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The Journal of HEREDITY

A monthly publication devoted to Plant Breeding Animal Breeding and Eugenics

DECEMBER, 1919

Vol. X, No. 9

THIS ISSUE

DEVOTED ENTIRELY

TO TWINS

ORGAN OF THE
AMERICAN GENETIC ASSOCIATION
WASHINGTON · D. C.

Printed for Circulation among Members only

Acceptance for mailing at the special rate of postage provided for in section 1103, Act of October 3, 1917 authorized December 20, 1918.

The American Genetic Association

An incorporated organization devoted to promoting a knowledge of the laws of heredity and their application to the improvement of plants, animals, and human racial stocks.

Its membership is composed of men of science, teachers, publicists, physicians, clergymen, parents, students, horticulturists, and breeders of live stock throughout the world.

The Association owns the JOURNAL OF HEREDITY, which is published monthly and sent to each member without additional cost. Every member is thus a part owner of the Journal.

Membership imposes no burdensome obligations. The Association, which is cooperative in nature, welcomes assistance in research, but does not demand it. Members are invited to submit discussions of the results of their research, accompanied by new and unusual photographs. All papers received will be given full consideration by the editorial board.

Hundreds of members are engaged in collecting facts about inheritance, and making experiments to determine the laws of heredity. Their discoveries are of fascinating interest and far-reaching importance to the city dweller and the country dweller alike. These findings are being reported and discussed every month in the Journal, and in no better way can serious minded people keep abreast of one of the greatest movements of modern science.

REQUIREMENTS FOR MEMBERSHIP

Subject to the approval of the Council, any person interested in the improvement of the human race or the creation of better varieties of plants and animals, is eligible for membership.

The Association welcomes all who are interested in its program, and the Secretary will be glad to answer any inquiries.

Annual dues, giving the right to attend all meetings, and receive the JOURNAL OF HEREDITY, are $2 within the United States and its possessions; $2.25 in Canada, and $2.50 in all other foreign countries; life membership, $50.

If you are not already a member, and want to become one, or if you know of anyone whom you think is interested in membership, write to

THE AMERICAN GENETIC ASSOCIATION

Box 472, Eleventh Street Station **Washington, D. C.**

The

Journal of Heredity

(Formerly the American Breeders' Magazine)

Vol. X, No. 9 December, 1919

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A year ago the American Genetic Association announced its desire to communicate with twins living in any part of the world. The response has been highly gratifying. Six hundred twins, and parents of twins, have written letters, and approximately 175 photographs were received. This entire number of the JOURNAL is devoted to discussions based on this correspondence.

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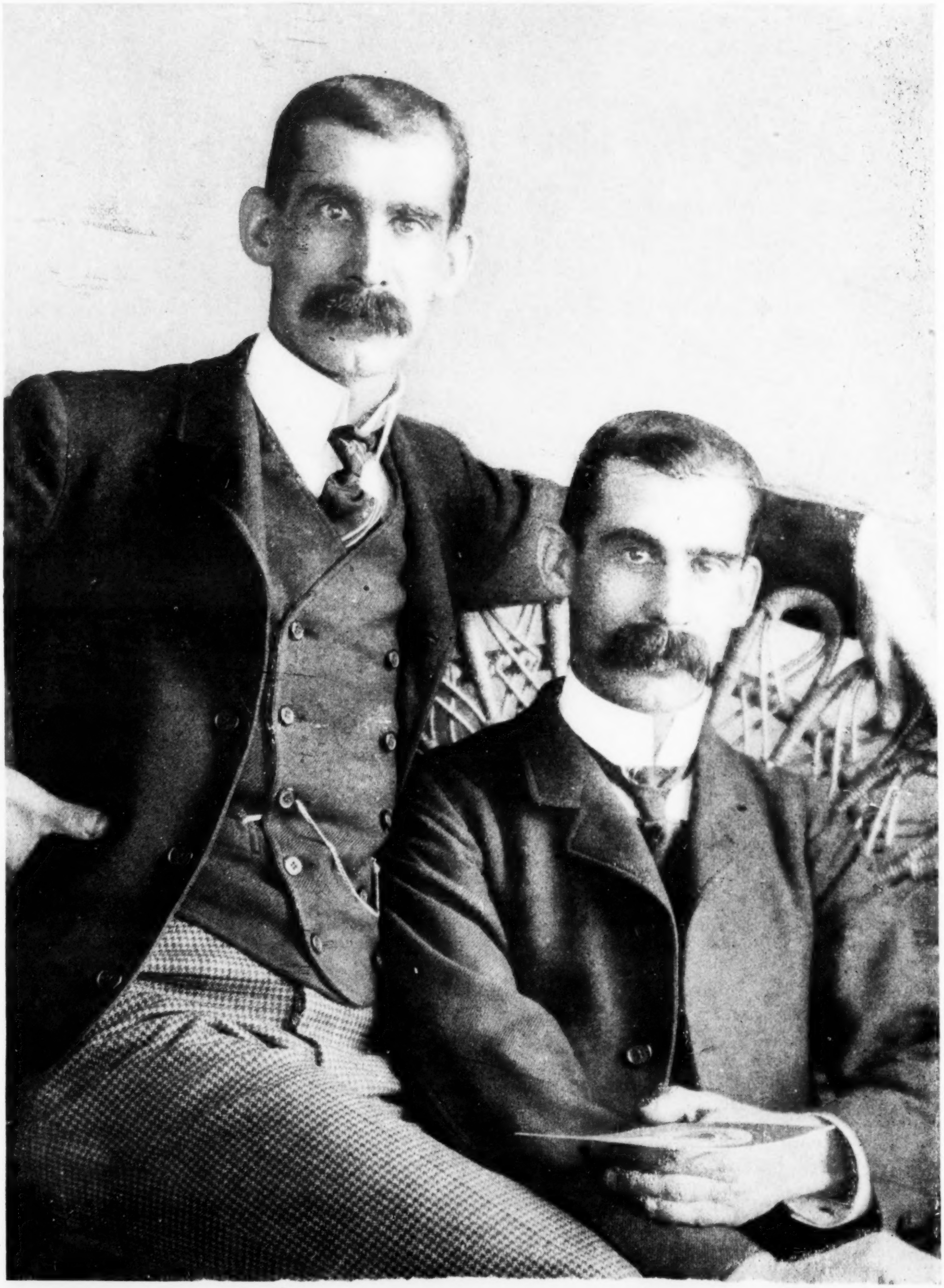
The Journal of Heredity is published monthly with the exception of July, August and September by the American Genetic Association (formerly called the American Breeders' Association) for the benefit of its members. Canadian members who desire to receive it should send 25 cents a year, in addition to their regular membership dues of $2, because of additional postage on the magazine; foreign members pay 50 cents extra for the same reason. Subscription price to non-members, $2.00 a year, foreign postage extra; price of single copies, 25 cents.

Entered as second-class matter February 24, 1915, at the postoffice at Washington, D. C., under the act of August 24, 1912. Contents copyrighted 1919 by the American Genetic Association. Reproduction of articles or parts of articles permitted provided proper credit is given to author and to the Journal of Heredity (Organ of the American Genetic Association), Washington, D. C.

Date of issue of this number, DECEMBER 24, 1919.



COULD TWO LIVING BEINGS BE MORE ALIKE?

In height the same, in weight the same, in tastes, in dispositions and in talent the same, these twin brothers have worked together for twenty-five years and have never been separated. Nine persons out of ten cannot tell them apart. What possibilities in the field of education lie in a study of twins like these? How far could they by different environments be forced apart in character? Supposing one grew up in China, speaking only Chinese, the other in Spain, speaking Spanish, would they still look as much alike as they do, and when we came to know them would they seem as much alike? (Frontispiece)

TWINS

Their Importance as Furnishing Evidence of the Limitations of Environment

DAVID FAIRCHILD

IDENTICAL twins are the only human beings in the world who have exactly the same heredity. If we can find out the characteristic ways in which they remain the same throughout life, the qualities and habits and mannerisms which persist unchanged in them both, in spite of their living in entirely different surroundings, we shall know much more than we do at present about what attributes are hereditary and fixed and what are those which we can hope to modify by environment and education.

THE INFLUENCE OF HEREDITY AND ENVIRONMENT

In all our experiments in education and civic improvements and in our dealings with different races we are always hampered by our ignorance of that great unknown quantity, heredity, and its influence on the people with whom we are dealing.

Any exact knowledge we can gain by a study of two identical twins who were separated from each other as babies and brought up in different towns under entirely different circumstances, scarcely knowing each other, will give us a clearer idea than we appear to have now, of what changes in our bodies, and perhaps, too, in some of our mental and moral characters, are clearly due to the things we eat, the exercise we take, the associations we make, and the work we do—to our environment, as it is called—and what changes, or failures to change, can be correctly traced to our very beginnings in that momentous meeting of the two parent cells which began our earthly lives.

WHAT DETERMINES OUR CHARACTERISTICS

It is strange to think of the way our inheritance comes to us, to realize that all we are to inherit from our mother and from her entire family is contained in a single tiny cell, while all that we are to inherit from our father and his family is contained in another tiny cell. When these two cells meet they become one larger cell and form the beginning of a new individual.

It is wonderful and almost passing belief to realize that a single microscopic cell holds so much of our destiny within itself and that it contains the mechanism which will determine the color of our eyes, the shape of our nose, the love of music, the taste for literature, for law or for science, the quickness of temper or sullenness of disposition which will go so far in deciding what our future is to be. All that the generations of ancestors behind us can give us of themselves, they give us through this tiny cell.

This cell grows and divides into two cells; each of these grows and divides into two more cells, and so the process goes on, controlled by the mechanism contained in the original cell—that mechanism, the so-called chromosomes which are easily visible through the microscope.

No two mother cells are alike, nor any two father cells; each contains a different arrangement of the hereditary characteristics, and so it is that every individual produced by the union of a father and mother cell is different from one produced by any other union. Although they are brothers and sisters, with the same heredity characteristics behind them to draw from, they have inherited these characteristics in such varying arrangement that they may vary as much as did the hundreds of people who were their ancestors on either side of the family.

A SINGLE DIVIDED CELL PRODUCES TWINS

Now it sometimes happens—we do not yet know why—that this original cell, made from the two parent cells, in one of its earliest divisions splits entirely in two, and the two halves, instead of remaining together as they usually do, remain separate and grow into separate individuals. In this case the two new individuals will have exactly the same heredity, and they are the only human beings we know of who have, and it is such individuals whom we speak of as identical twins. They are always of the same sex and always resemble each other to an extraordinary degree throughout the whole of their lives. Fraternal twins, who do not resemble one another, and who may not even be of the same sex, are the product of two unions of two different mother and father cells, and have simply happened to be born at the same time.

There are cases where two of triplets appear to be identical twins and the third to have originated from a separate cell. Cases of identical quadruplets are theoretically possible by assuming that the fertilized cell splits into four quarters. If one of these failed to grow, identical triplets would result.

IDENTICAL TWINS LIKENED TO DIVIDED PLANTS

We have then, in these identical twins, cases of human beings who start out, not as two different mixtures of the free and variable cells of their parents, but as halves, so to speak, of one mixture. To roughly illustrate the difference let us take two apple seeds. They have come from the same apple, but they will not grow into apple trees producing the same kind of apples. One may produce a tree which has a very fair apple on it; the other may produce apples which are too sour or bitter to eat. The trees themselves may even be distinctly different; one may grow upright and the other be spreading. The explanation is that they have different heredities at the very start—different pollen grains from a flower on the same tree have fertilized different egg cells in the young fruits. Supposing, however, we were to *divide a single seed* from an apple and that these two exact halves grew, would we not then be able to produce two apple trees which looked alike and which, when they bore, had almost exactly similar fruits on them? While it is not possible to divide the seed, horiculturists have found that they get almost the same result by dividing the plants after they are partly or entirely grown up. The whole great fabric of our cultivated varieties of fruit trees is built up on this approximate identity of the heredity of trees produced by growing them from parts—buds—taken from a single remarkable tree which produces delicious fruits, and putting them where they can grow and form thousands of orchard trees. Millions of navel orange trees, all of which produce fruits so much alike that even one who is not an expert can tell they are navel oranges at a glance, came in this way from a single bud which was put into a bitter-orange tree in Riverside, Cal., in 1870. The reason these all look so much alike, even though grown in California or Florida, is because their heredity at the very start was so nearly identical. They are not all *absolutely* alike as they are influenced by the climate and soil in which they grow. The flavor of a navel orange grown in Florida is different from one grown in California and quite as different from one grown in Bahia, Brazil, where the first buds came from; but they all have the navel which is so characteristic of the variety as to have given it its name.

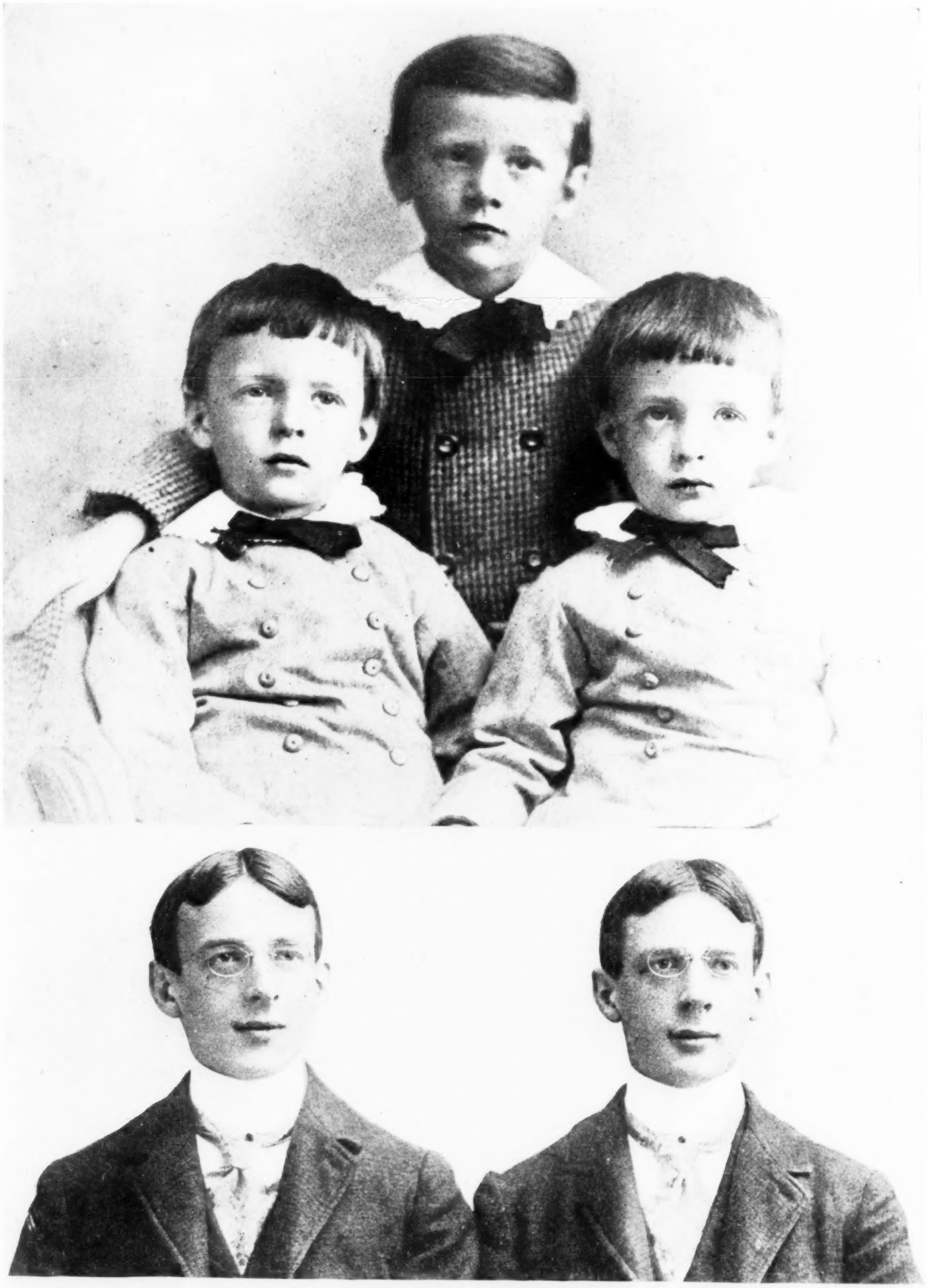
Roughly speaking, then, identical twins can be compared with plants which have been propagated by the division of one individual.

ALL DIFFERENCES NOT APPARENT IN PHOTOGRAPHS

There are certain questions which may arise in the minds of those who look at these photographs. I surmise these will mainly deal with their invisible differences — differences in temperament, mental ability, tastes, mechanical abili-

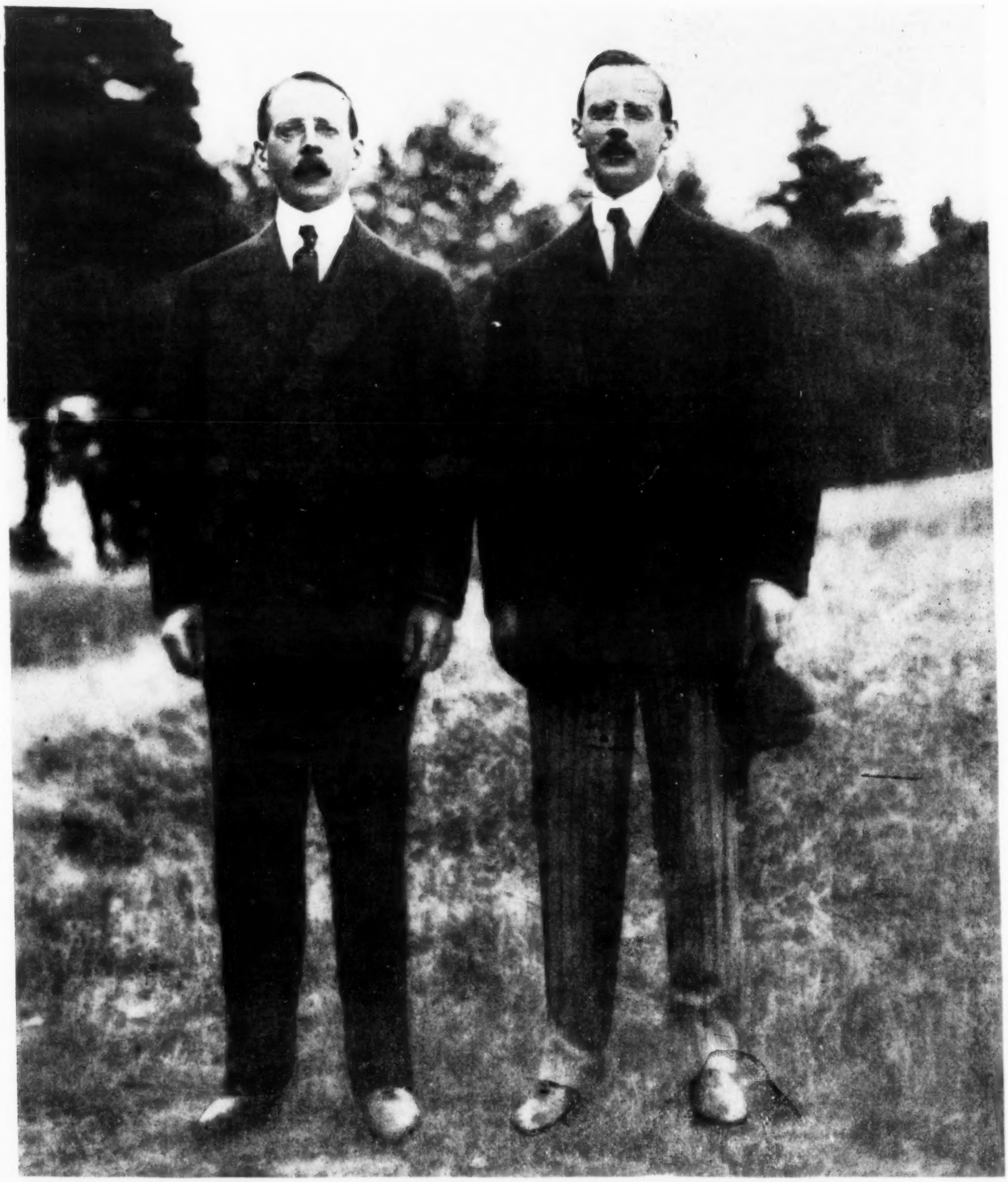
TWIN ACROBATS

Even their mother cannot always tell Robert and Frank Michel apart; once she bathed the same little fellow twice. They are very much attached to each other and do not care to be separated for one minute. They even get hungry and sleepy at the same time. Although they are only five years old, they are clever little acrobats and work for moving-picture companies. It is interesting to know that their maternal grandmother was also a twin. (Fig. 1.)



EMINENT TWINS AS BOYS AND YOUNG MEN

The upper photograph is of Gilbert and Edwin Grosvenor with their older brother, Asa, as boys of four and a half years of age. The lower photograph is of the twins as students at Amherst. (See also following page.) (Fig. 2.)



EMINENT TWINS TODAY

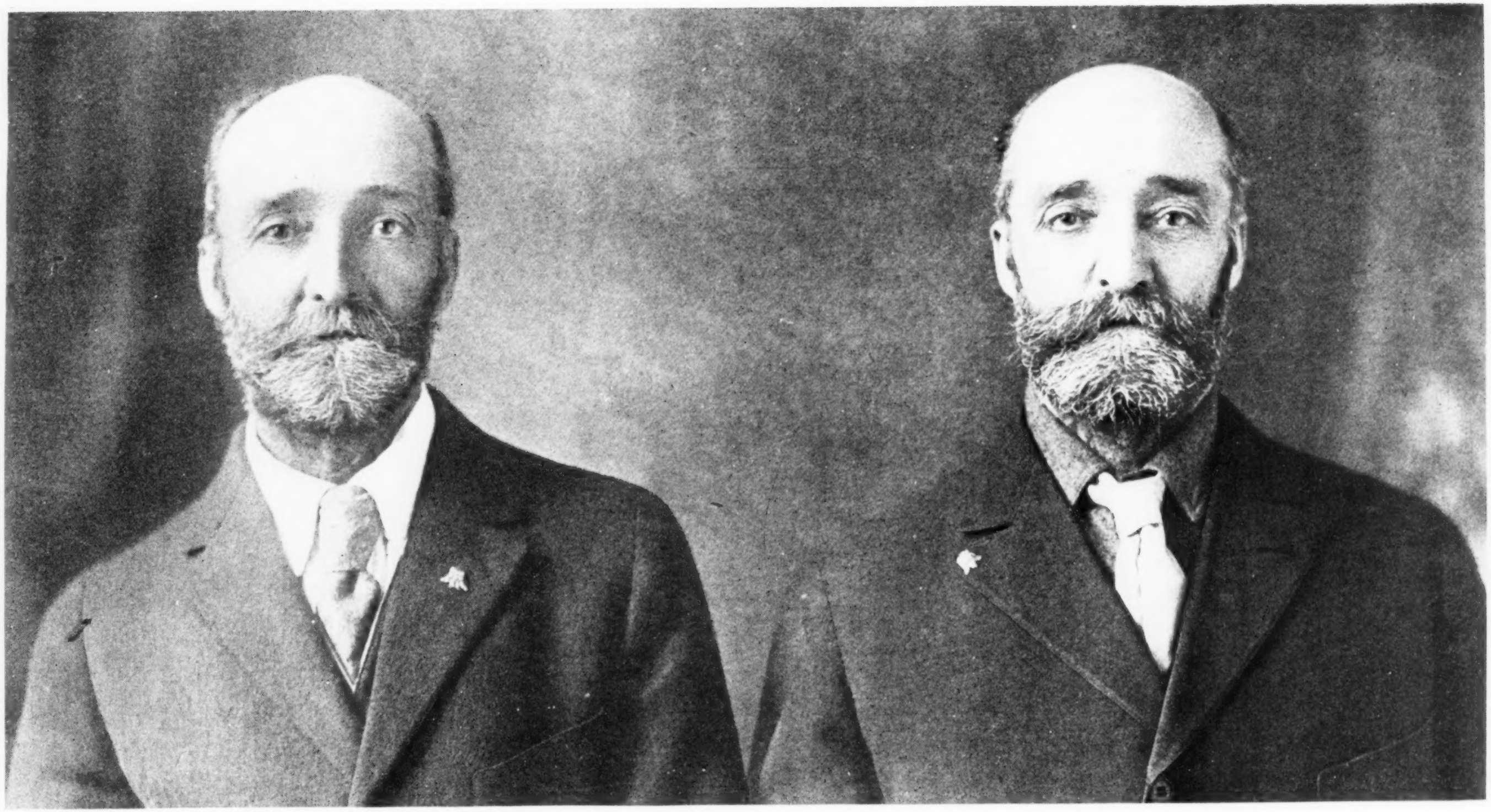
If there were any theory that identical twins, starting from only half a cell, are lacking in mental or physical vigor, the record of the Grosvenor twins would shatter it. They both, as students at Amherst College, divided highest honors in the class room and on the tennis field, and one, as builder and director of the National Geographic Society, and the other as Assistant Attorney General and partner in one of the most important law firms in America, have demonstrated their abilities as leaders.

During their whole lives they have never varied more than a pound in weight. In college their grades never varied more than one-tenth of one per cent. Their tailor says that one of the twins has a short left arm and the other a short right arm. Although absolutely dependent upon glasses, each can wear the other's.

Their illnesses have often coincided. They have always been devoted friends, and frequently their letters cross. Most of their tastes are similar, but they never agreed when it came to girls. (Fig. 3.)

A MACHINIST AND A COMMERCIAL MAN

So near of a size that one can wear all the other's clothes, with color of hair, complexion and weight the same, differing in their taste for mathematics, but with voices considered identical, with an unusual fondness for one another, and with similar taste for classical and operatic music, the Ploger brothers of Owosso, Michigan, illustrate the presence of hereditary forces which keep those of practically identical heredity curiously similar through life. (Fig. 4)



ARE THESE ALIKE IN CHARACTER?

Anson and Friend Ingraham are now fifty-seven years old. That they are strikingly alike in appearance nobody will deny, and one wonders if they are alike in character.

What constitutes similarity of character? How could two souls be so alike as to be indistinguishable to their friends? How much variation in the physical structure of two brains would be required to produce quite different personalities? These questions, if studied more exhaustively, should bring us closer to an understanding of the physical basis of personality.

Mr. Anson E. Ingraham and his twin brother, Mr. Friend E. Ingraham, though no longer living in the same town, look as much alike as when they were boys. (Fig. 5.)

ties, etc. Let me suggest, as Dr. Frederick Adams Woods has pointed out, that we do not know how great or how small are the physical differences which are associated with very considerable differences in these invisible mental and moral characteristics. A close study of these photographs will reveal that no two of the most similar twins are absolutely alike. Perhaps there is some slight difference in the lobe of the ear or the direction of the hair on the forehead. Supposing there were as slight a difference in the lobes or convolutions of the brain, who knows what changes in intellect this might bring with it?

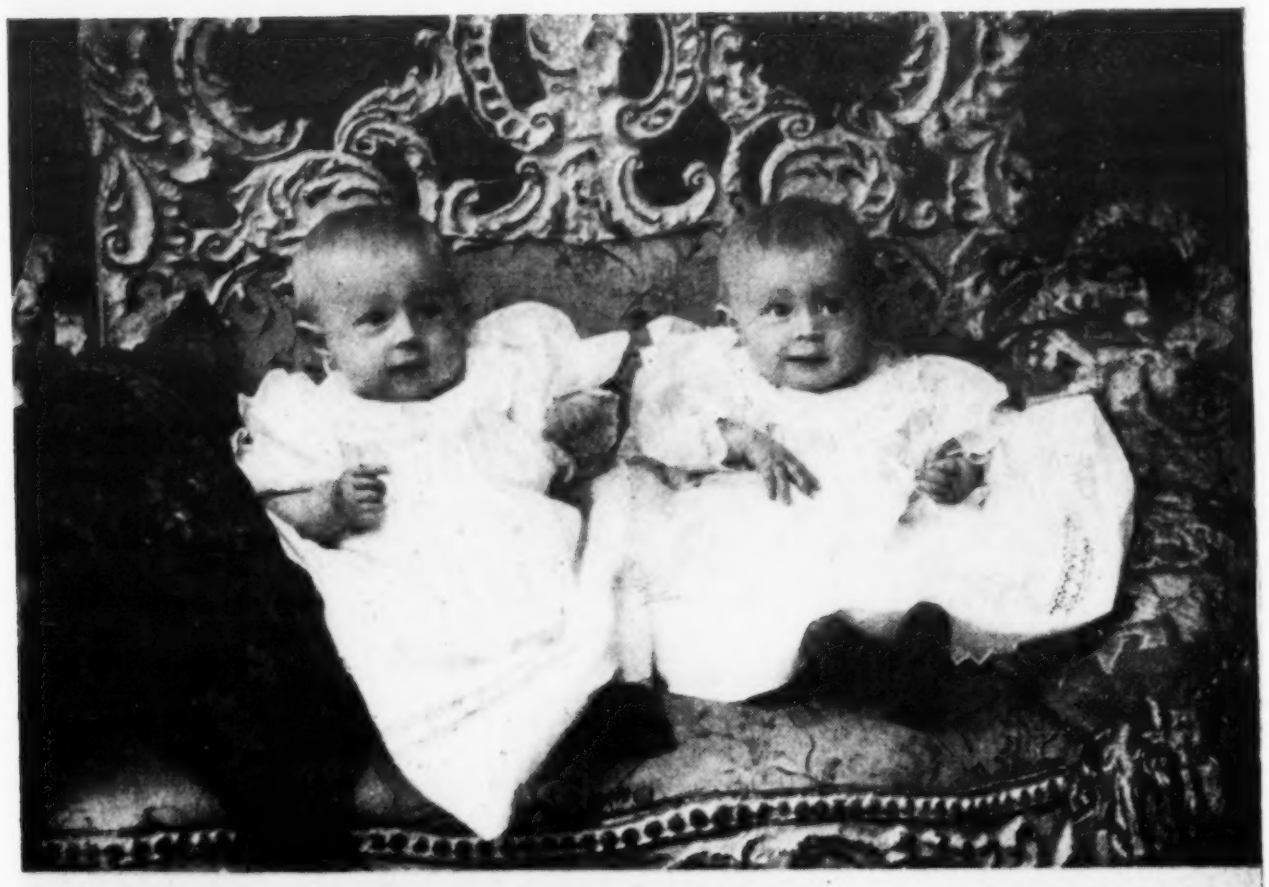
In studying these photographs and judging of their likenesses or unlikenesses, the fact ought to be kept in mind that our eyes are more critical about faces than about almost anything else. From babyhood we have studied each other's faces. Down through the ages from geologic times man has made a study of the human face, and it is hardly to be wondered at that he has a remarkable memory of its form and can tell at a glance whether he has seen a face which he once saw years ago. This form memory, heightened no doubt by natural selection, we bring to bear on these photographs, and differences so slight as to escape our attention in horses or dogs are immediately detected by us in these photographs.

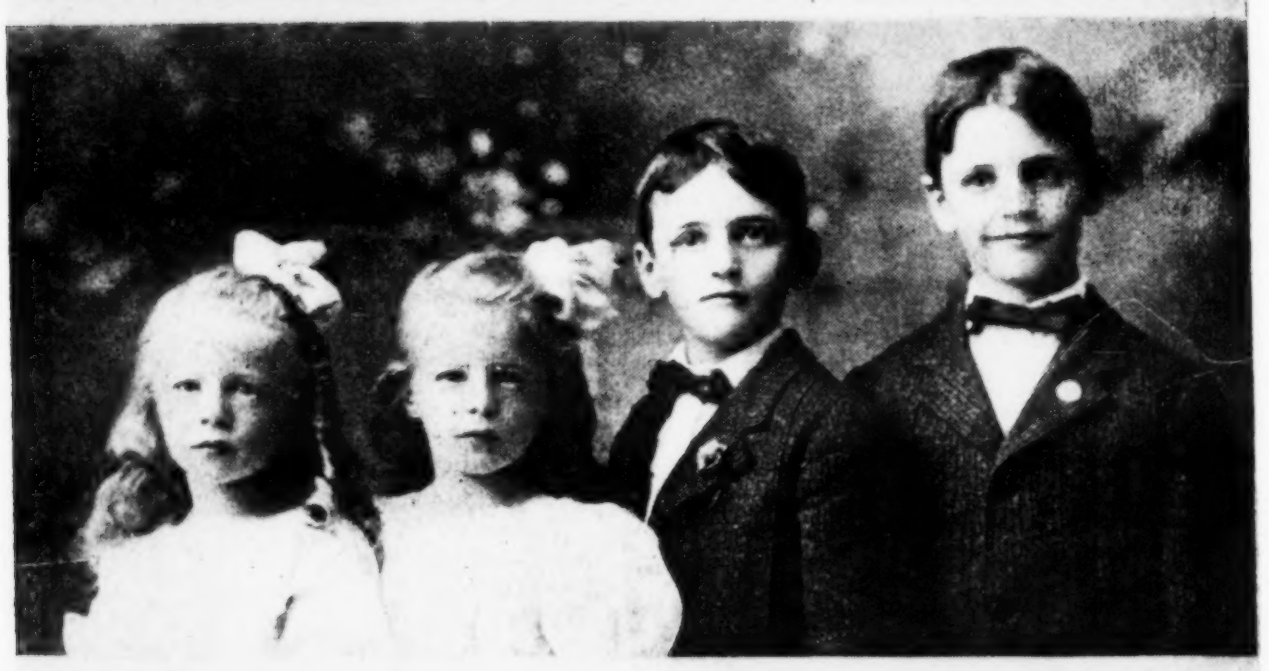
It may not appeal to some as important that we learn which of our characteristics are hereditary and which are environmental, but to those who have given serious attention to the subject the matter appears to be of transcendent importance, involving as it does the whole question of our attitude towards each other as human beings, our understanding of the great race question, the limitations of education in the elevation of races, and the understanding of the fact, which is being continually lost sight of, that *acquired characters are not inherited*, and that education affects only the generation to which it is given.

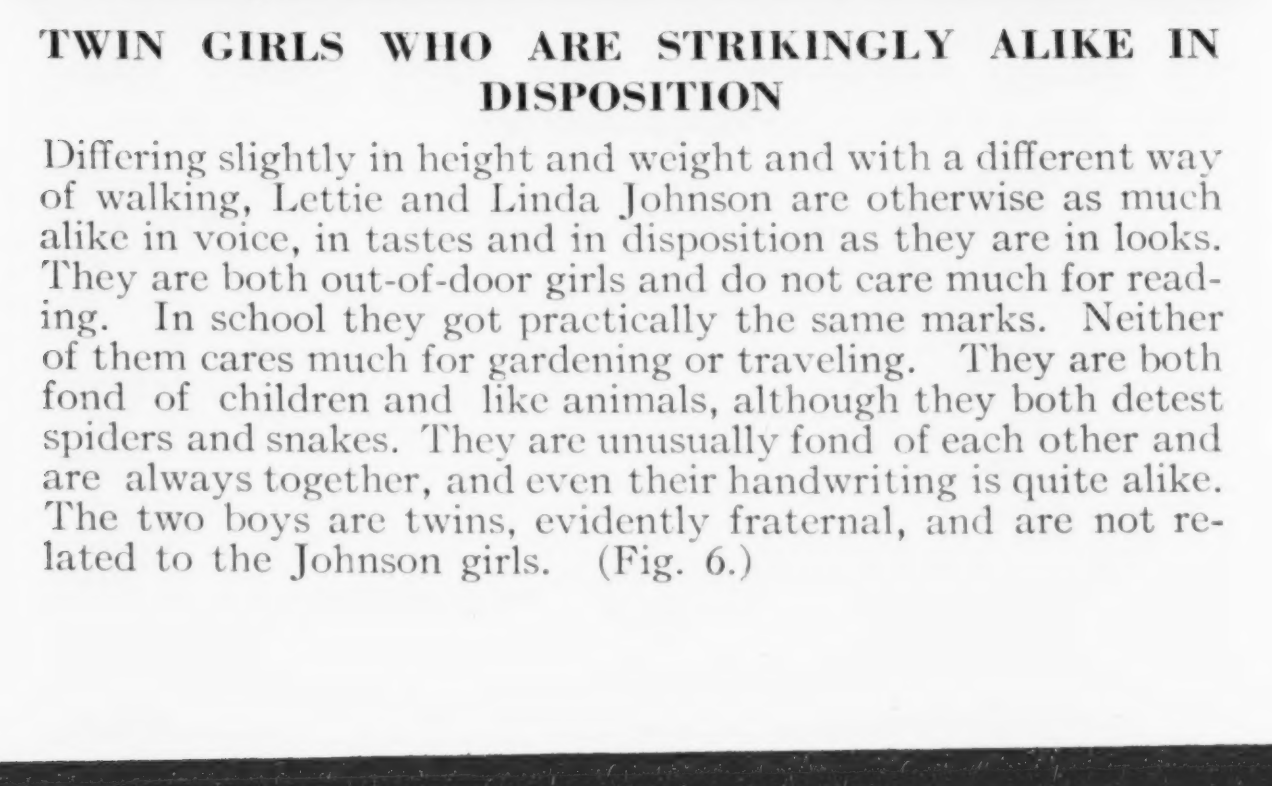
Some of the most violent of our so-called race antipathies are based upon characters which are entirely environmental. Language is one of these. But table manners, fashions in foods and clothes and methods of living, styles of architecture, forms of address, attitudes towards music and painting, behavior in the relation of the sexes, emotional likes and dislikes on sight, respectfulness and attractiveness, obedience and disobedience, honesty and dishonesty, bravery and cowardice—all these reactions of the individual to his surroundings must be studied from the double standpoint to determine how far the response is the result of environment, and how far it is the result of heredity, for both factors are certainly there and must be given their proper weight.

When the barbers ascribe to the wearing of hats the bald heads of the old men, they are neglecting to give the right weight to the fact that a man inherits his particular type of baldness. When a woman ascribes her alarming increase in weight to the food she eats, she is often neglecting to consider the fact that she may have inherited the tendency to become large from her mother or her father, and the fact that she had a sylph-like form as a young girl tallies with the behavior of her mother or father when they were young. The old man past seventy who becomes convinced that his long life was caused by his not using tobacco or the fact that he never ate any butter, or that he always walked a mile or two a day, or that he took a cold bath every morning even if he had to break the ice to do it, should not overlook the fact that he comes from a long-lived ancestry nor that other fact, pointed out by Dr. Alexander Graham Bell,[1] that of 1594 individuals examined only 5% of those whose parents (both of them) died under eighty, themselves lived to be eighty; 10% of those having one parent who lived to be eighty and 20% of those having both parents who lived to be eighty, lived to be eighty.

[1] "The Duration of Life," Volta Building, Washington, D. C. "Who Shall Inherit Long Life" *Nat. Geographic*, June, 1919.







TWIN GIRLS WHO ARE STRIKINGLY ALIKE IN DISPOSITION

Differing slightly in height and weight and with a different way of walking, Lettie and Linda Johnson are otherwise as much alike in voice, in tastes and in disposition as they are in looks. They are both out-of-door girls and do not care much for reading. In school they got practically the same marks. Neither of them cares much for gardening or traveling. They are both fond of children and like animals, although they both detest spiders and snakes. They are unusually fond of each other and are always together, and even their handwriting is quite alike. The two boys are twins, evidently fraternal, and are not related to the Johnson girls. (Fig. 6.)

It seems to be a universal habit to ascribe a cause to every effect and one's peace of mind is satisfied in this way, whether there is any real proof of the connection between the two or not.

This collection of photographs of some of the more interesting of the 150 photographs of twins is published with the object of bringing to the attention of the readers of THE JOURNAL OF HEREDITY the existence of thousands of human beings who have gone through changes of environment which we have been in the habit of considering sufficient to acount for all sorts of effects without varying enough in their likenesses to each other to make them easily distinguishable.

These photographs are published for the purpose of putting into the minds of as many people as possible this illustration of the force of heredity, so that they will appreciate the importance of the work of those men who are pushing into the field of its study. The field is worthy of the attention of the most brilliant minds of this age, and those who are successful in increasing the sum of our knowledge of it will most certainly be benefactors of the human race.

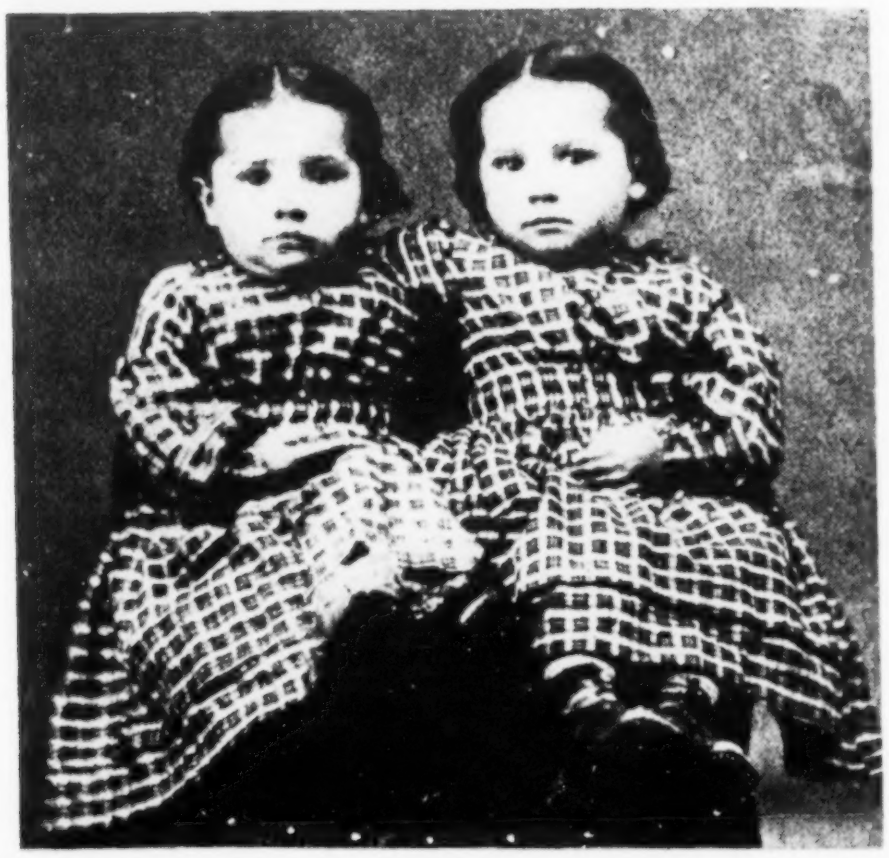
Should we not always remember that the sum total of our knowledge as compared to the future acquisitions of the human mind is as nothing; that we stand looking out on the world with the same blindness of vision that the mariners had when they saw every day the masts of the approaching vessels before the hulls appeared and failed to interpret the fact to mean that they were sailing round a gigantic globe?

I have some such impression when I look at this collection of the photographs of identical twins—identical from their babyhood through to old age. A study of them cannot be a trivial thing, and somewhere there must be a mind which will assemble the facts about them and bring these to bear on the greatest problem of the world, which is the understanding of what constitutes human progress.

COÖPERATION FROM THE TWINS

To those who have so generously volunteered themselves — and there were over 600 of them—as subjects for the study of the specialists of the American Genetic Association, I wish to express the deepest gratitude. Nothing has occurred since the establishment of the association which has so encouraged its officers as this response from the Twins of the World. It has given them a feeling of confidence that there is deep in the consciousness of everyone a keen interest as to what character of human race is to inhabit the globe after we are gone. That this interest will grow until it occupies the highest and most important place in human consciousness is the conviction of students of the new science of genetics.

The special studies made from the data supplied by the Coöperating Twins will be published from time to time in THE JOURNAL OF HEREDITY, and such of the photographs as have been given to the association will be kept for reference purposes.



BOTH MARRIED BUT ONLY ONE WITH CHILDREN

For the first eighteen years of their lives, Rose and Louise Briot were always together, needing no other chums. Since then their lives have varied greatly. One is a widow and lives in the west near her children and grandchildren; the other is married but has no children and has lived always in Chicago.

Although their environment has been so different, the similarity between the twin sisters is in no way lessened. Their friends do not tell them apart any more easily, either when they see them or when they hear their voices over the telephone. As girls they often voiced each other's thoughts, and even now their letters cross repeatedly. Their mother, besides having twins herself, has twin great-grandchildren, and her brother has twin grandchildren, though neither pair are identical. (Fig. 7.)

THREE PAIRS OF TWIN GIRLS

Of the top pair their aunt writes that few can tell them apart, that there never has been more than a half pound difference in weight or a half inch difference in height.

Concerning the middle pair we have no information but their names and ages.

Mrs. Vera De Mott, of Battle Creek, Mich., and her twin sister (lower pair) were separated when three years of age and have always lived apart, seeing each other at long intervals only, yet that peculiar affection common to identical twins has always existed between them, and their characteristics have been so similar that even their best friends cannot tell them apart when they meet. (Fig. 8.)

RESEMBLANCE AND DIFFERENCE IN TWINS

Twins That Look and Act Alike Attract Attention First, While Dissimilar Ones Are Apt to Be Overlooked

C. H. Danforth
Department of Anatomy, Washington University School of Medicine

AS EXPLAINED elsewhere in this number of the journal, the American Genetic Association began some time ago to accumulate a collection of photographs of twins. After a considerable number of twins had been found, a questionnaire was sent out to get data on resemblances and differences between the members of twin pairs. It is the purpose of this paper to discuss briefly some phases of the question that were emphasized by the answers received. The writer is indebted to the president of the Association for putting all the material at his disposal.

TWINS NOT ALWAYS ALIKE

Some of the photographs reproduced in this issue bear witness to the remarkable degree of facial resemblance that may exist between twins, while others illustrate the fact that twins are sometimes surprisingly dissimilar. What the photographs show with reference to facial resemblance, the questionnaires, filled out by the twins themselves, show for other traits, both physical and mental. While all types of twins are represented in the replies, there is some evidence, as will be explained below, that the material on hand comes from a somewhat selected group. For this reason it does not seem wise to present a tabulated summary of the answers. Such a tabulation would give the impression that the average resemblance of all twins is higher than it really is.

The questionnaire was so planned that it would afford data for comparing purely physical, more or less physiological, and mental traits including likes, dislikes and normal reactions. The answers may be briefly summarized under general headings.

Height.—Exact correspondence in height is not unusual, and a difference of a quarter of an inch or less is common. On the other hand, variations of several inches sometimes occur, and considerable differences are occasionally found between twins that are otherwise very similar.

Weight.—The resemblances and differences in weight are similar to those for height, but there is no absolute correlation between the two traits. Complete identity, or a difference of only a pound or two, is common. Some twins state that, while their weight fluctuates, the changes are always parallel so that they never differ from each other by more than a small amount. In other cases there is a wide divergence even when height and many other characteristics are similar.

Eye and Hair Color.—These features are generally given as similar. For example, one twin speaks of a "switch," perfectly uniform in color, made from the combings of both heads. Nevertheless twins, of which one is dark with brown eyes, the other light with blue eyes, are rather frequent.

Other Physical Traits.—So far as can be judged by the answers, other physical traits follow the same general rule as those already mentioned—almost complete identity in some cases, and wide divergence in others. In general, similarity with reference to one trait is correlated with similarity in reference to most other traits. Rarely are there only a few points in common;

still more rarely, what are otherwise similar twins may be characterized by one or two points of difference. As an illustration of the latter class, there may be mentioned a pair which in a baby show were scored as identical except for the shape of the occipital region of the head.

Physiological Traits.—Such manifestations of the general make-up as gait, sound of the voice, reaction to foods, susceptibility to disease, all show a distribution similar to that of the purely physical traits. One pair of twins state that bananas make them "both very sick." Another pair have no special aversion for any food but tapioca. Still another pair agree in all their likes and dislikes except for canteloupe. In other cases the lists of preferences differ very considerably.

THE "MIRROR IMAGE" OF EACH OTHER

Perhaps the matter of right and left handedness should not be passed over in this connection. Rather a surprising number of twin pairs seem to be composed of one right and one left handed individual. It has been suggested that one twin is frequently the "mirror image" of the other, left-handed and with heart and other viscera reversed in their symmetry. The responses to the questionnaire do not show definitely whether or not this condition, known to anatomists as *situs inversus*, occurs in any of these twins. Some persons believe that right or left handedness is an acquired characteristic and not hereditary. While this position probably cannot be maintained, it may be of interest to recal that twin babies generally face each other in their beds, and if care is not taken to change them about frequently their heads become asymetrical on opposite sides. This may possibly affect the hemisphere of the brain differently and certainly influences the amount of use that is made of the left hand in one infant and the right in the other.

Handwriting.—Each twin was asked to copy a short sentence. The handwriting of the two members of a pair frequently showed great similarity and in one case was virtually identical. In other instances the differences in style and other characteristics were very noticeable.

Mental Traits.—Much of the information received through the questionnaires concerned mental capacities, intellectual tastes, and likes and dislikes. Without analyzing this data in detail it may be stated that ample evidence is afforded that the same resemblances and differences obtain with reference to mental traits as are found for characteristics that are generally thought of as more purely physical or physiological. Over and over the two twins of a pair enumerate virtually the same list of preferences and aversions One pair of twin girls heartily dislike mathematics, while another pair record it as their favorite study. One twin mentions that not only do she and her sister commonly dream about the same person at the same time but they dream the *same things* about them. She states that this happens even when they are in different places.

STRONGER AFFECTION

Many twins state that their fondness for each other far exceeds their liking for other brothers and sisters. Both men and women twins write that they are always dissatisfied when separated from their co-twins. "No one was ever quite so entertaining to us as the other." It is noticeable that twins who express this sentiment are not only of the same sex, but otherwise similar.

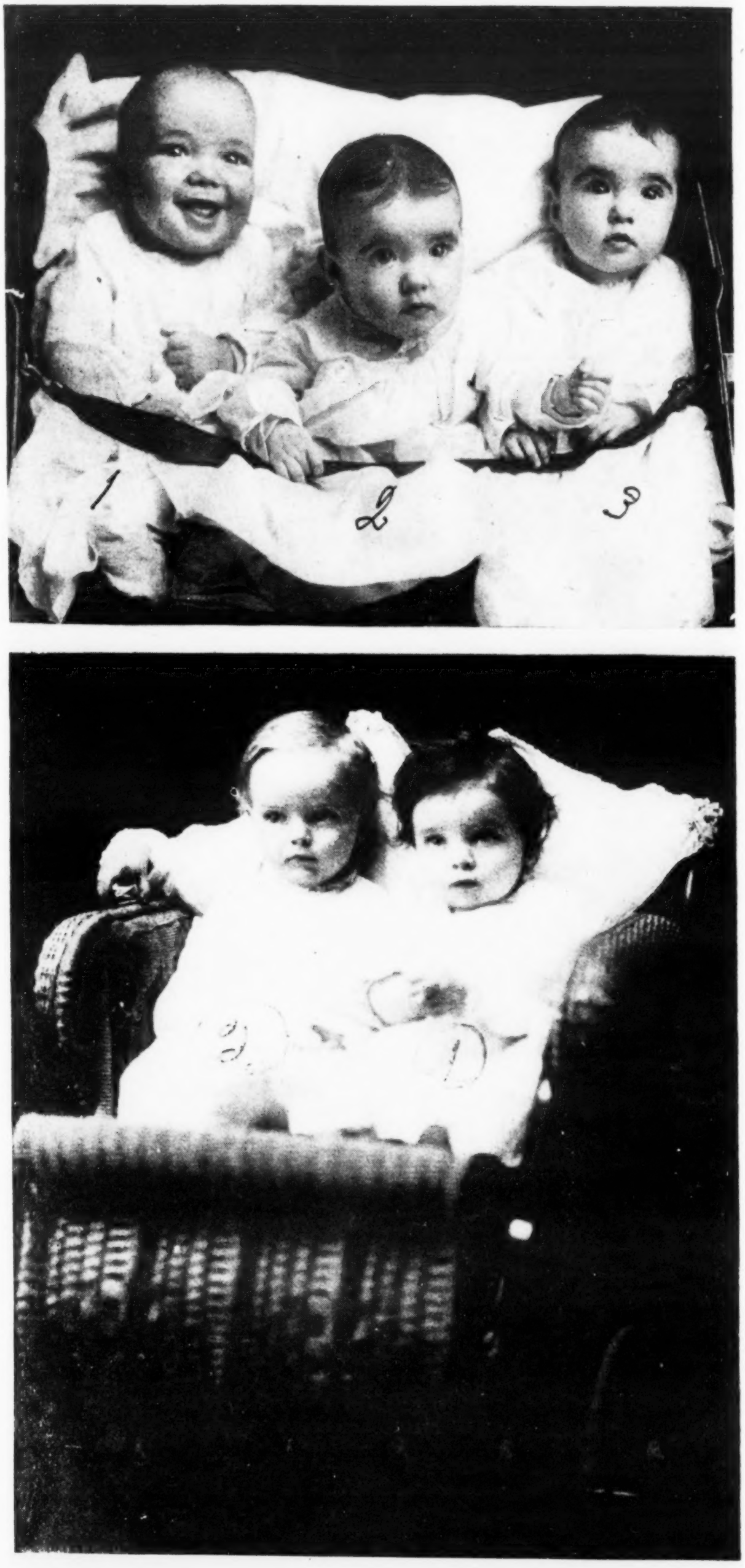
On the other hand there are plenty of twins who differ widely in their tastes and capacities and who find their co-twin no more congenial than their other brothers and sisters, indeed sometimes less so. These are the "Jacobs and Esaus," as a twin in an insane asylum once explained to the writer.

Summary.—Summarizing this very sketchy review of the questionnaires, it may be said that there is ample evidence that the twins of certain pairs show profound resemblances in both physical and mental traits, while those of other

TWINS AS DIFFERENT AS ANY SISTERS

These little twin sisters have grown up together in the same surroundings and under the same influences; even their prenatal influences were the same. Yet they are so unlike as to be almost opposite in every characteristic, so much so that their education and management has been quite a problem.

These two girls, born at practically the same time, of the same parents, and yet with such different characteristics, illustrate clearly the difference between identical parentage and identical heredity. Both are mixtures of the same two human stocks—the maternal with its long line of ancestors and the paternal with its own line. But each girl is a different mixture or combination of these stocks—in one more of the paternal perhaps and in the other more of the maternala ppears. They doubtless arose from separate egg cells. (Fig. 9.)



STRIKING CONTRASTS DUE TO DIFFERENT HEREDITY COMBINATIONS

These triplets, in the top picture, show in a very striking way the difference between fraternal and identical twins. The two little girls at the right are probably identical, while the boy at the left has evidently a very different combination of the hereditary elements of his parents. The mother of the little twin boys, shown at the bottom, writes that they are so "utterly unlike in every way that it is hard for anyone to realize they are twins." (Fig. 10.)

ENGLISH TWIN GIRLS

In each of these photographs of the Misses Stallard of Portsmouth, England, one of the twins holds her head down a little, while the other one holds hers up. If it is the same one who does so in each picture, it is probably a characteristic difference, but that seems to be the only difference there is. (Fig. 11.)

pairs show no such unusual similarity. The resemblance between similar pairs is never quite complete and practically every pair is found to differ more or less widely in at least one respect. On the whole one might gain the impression that while absolute identity is not attained, rather marked similarity is, with rare exception, the rule.

DIFFERENCES AND SIMILARITIES EXPLAINED

It may now be of interest to seek an explanation for these likenesses and differences, and particularly to try to explain the intermediate grades of resemblance

The similarities of some twins and the differences of others are commonly explained on the familiar assumption that there are two classes of twins, those derived from a single ovum and those derived from two separate and independent ova.[1] The former, having identical heredity, are similar, while the latter, arising from different ova and different sperms, are dissimilar. Both of these types furnish strong evidence for the overwhelming potency of factors of heredity as compared with those of environment. In the one case the resemblance persists, as can sometimes be shown, in spite of dissimilar environments, while, in the other, identity of home surroundings, food, and even clothes fails to lessen inborn differences.

It cannot be maintained, however, that heredity is the sole factor in determining the characteristics of the individual. Thorndike[2] has found, for example, that many twins which are undoubtedly biovular in origin resemble each other more than they resemble their other brothers and sisters. While this is not Thorndike's conclusion, the observation might be interpreted as indicating the possibility of an environmental influence. Since it is also to be observed that uniovular twins are never quite "identical," it is conceivable that their differences might be due to environmental factors. How far such similarities in the one case and differences in the other are in reality directly induced by the environment cannot be easily answered. A few considerations bearing on this question may be of some interest. In this connection there are three questions that it may be profitable to consider: (1) Are the resemblances of uniovular twins confined to certain traits or does the similarity pervade their whole being? (2) Apart from environmental influences, how great is the similarity that may be expected between biovular twins? (3) How great are the differences that may be expected to appear in uniovular twins?

In regard to the first of these questions it will at once be apparent that many of the so-called superficial resemblances are in reality expressions of more deep-seated similarities. The color of the hair and eyes is due to fundamental factors in the make-up of the individual. The gait and many other peculiarities that might seem superficial are the product of the condition of the muscular and nervous systems. Some few dissections of twins have been made, and these revealed remarkable similarity in the configuration of the brain[3] and in the muscles and blood vessels.[4] So there is every reason to believe that the resemblances between twins are fundamental, involving all parts and systems. But while every part may be concerned, there is some indication that the total resemblance is due not to some general quality that the two individuals have in common, but rather to the sum of the many similar special traits which, added together, give the individual his character. On this assumption we can understand at least a part of the cases in which there is

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[1] For a fuller discussion of this matter the reader may referred to an article in this journal, vol. vii, No. 5, pp. 195-202, "Is Twinning Hereditary?"

[2] Archives of Philosophy, Psychology and Scientific Methods, No. 1, 1905.

[3] Sano F.: "The convolutional pattern of the brains of identical twins: a study on hereditary resemblance in the furrows of the cerebral hemispheres." Phil. Trans. Roy. Soc., Lon., Series B, vol. ccviii, pp. 3761, 1916.

[4] Danforth, C. H.: "A comparison of the hands of a pair of polydactyl negro twins." *Amer. Jour. Physical Anthropology*, vol. ii, pp. 147-165, 1919.

similarity in some respects and dissimilarity in others, for it may be assumed that the traits are not all quite identical. Stated in other words, there would seem to be evidence that all bodily and mental traits tend to be similar in certain (mostly uniovular) twins, but that it is not unusual in twins of either type to find differences, now in one trait and now in another.

EXTENT OF SIMILARITY IN BIOVULAR TWINS

In regard to the second question, it may be assumed that biovular twins will on the whole resemble each other to a degree about equal to the average for all children of the same family. In individual sets the degree of resemblance will vary widely, since the possible combination of traits from the maternal and paternal germ plasms are very many.[5] It is conceivable that occasionally (with our population and birth rate, perhaps once in eight or ten years) a pair of biovular twins would be born with identical germ plasms. More frequent should be biovular twins differing in only one chromosome, and progressively more frequent the pairs differing by larger and larger degrees until the average of fraternal resemblance is reached. Then progressively less frequent should be pairs differing to increasing degree below the fraternal average.

Since most pairs of parents have many points in common, perhaps selecting each other on the basis of community of physical as well as mental traits,[6] the possible average of combination of traits within a given family is somewhat reduced and the likelihood of children with similar germ plasm correspondingly increased. If two very similar children are born a few years apart, their likeness may be easily overlooked—the photograph of a boy at eight and the same boy at fourteen may show no more than a family resemblance—but when such similar children happen to be twins of the same sex, even though the degree of resemblance is such as could easily be matched in other brothers and sisters who are not twins, the similarity of age and frequently of dress immediately becomes noticeable. Such twins will pass among their friends as strikingly similar. It is interesting to note that in submitting photographs, many twins explain that they are really more alike than their pictures indicate. On *à priori* grounds, then, many pairs of biovular twins should be expected to show resemblances, either real or apparent, that would be much above the average for the ordinary run of brothers and sisters.

TWINS OF DIFFERENT TRAITS OFTEN OVERLOOKED

It will no doubt be objected that, for every pair of biovular twins which show a resemblance greater than the average fraternal resemblance, the laws of chance lead one to expect that there will be another pair that will show a corresponding dissimilarity, bringing the average resemblance down to that for brothers and sisters in general. Assuming that the distribution of traits in biovular twins at birth is in accordance with the laws of chance, and ignoring the possibility of subsequent environmental selection (*e. g.*, by disease) against dissimilarity in children, there remains an important factor to be considered in any study of twins that have passed the age of infancy. This is the likelihood of overlooking twins who do not closely resemble each other. Children who differ widely in general appearance, size, mental capacity and tastes are less likely to be together, more likely to leave school at different times and, curiously enough, often take little interest in the fact that they are

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[5] On the assumption that chromosomes maintain their individuality and that "crossing over" does not occur, there would still be no less than 4,096 possible kinds of germ cells to be produced by a given individual of either sex.

[6] Harris, J. Arthur: "Assortative Mating in Man." *Pop. Sci. Monthly,* vol. lxxx, pp. 476-492, 1912.

BORN AT THE SAME TIME BUT OF DIFFERENT SEX

Fraternal twins—like Merton and Myrtle Collins—are not more alike than if they had been born a year or two apart. Merton has blue eyes and fair hair and is near sighted, while Myrtle is dark with dark brown eyes and good eyesight. Except in mathematics their abilities are about the same, and they have quite similar likes and dislikes. They are unusually fond of each other. No cases of identical twins are known in which they differ in sex nor are such conceivable as our knowledge of heredity stands today. (Fig. 12.)

twins. In any statistical studies on school children or inquiries addressed to twins themselves this group tends to become lost, a fact that was interestingly brought out in the responses of twins to the requests for photographs. Of 160 pairs whose pictures were submitted 77 pairs were women or girls, 61 pairs were men or boys, and only 22 pairs were of both sexes, most of the last being children whose pictures were sent in by their parents. Statistics based on thousands of cases show that about one pair of twins in every three pair born consists of a boy and a girl, yet, despite the fact that the appeal sent out to the newspapers asked for pictures of twins irrespective of their sex or resemblance, "pigeon" twins were not sufficiently interested to coöperate or to show curiosity to any appreciable extent. Similarly, by an easy deduction,[7] it can be shown that twins of the same sex should be uniovular in about two cases out of five, yet in the opinion of the writer those twins of like sex who submitted their pictures show very striking resemblances in at least three cases out of five. This seems to indicate that even where both twins are of the same sex the interest in each other is roughly proportional to their resemblance.

The conclusion with reference to our second question would seem to be that biovular twins should be expected to show resemblances in hereditary traits ranging from practical identity to wide divergence, and that in any ordinary collection of photographs or data supplied by twins themselves or their friends they will *seem* to show an average degree of resemblance greater than that for brothers and sisters in general. That is, of course, entirely apart from any environmental influences that might be supposed to still further heighten their resemblances.

WHY ARE THERE DIFFERENCES IN UNIOVULAR TWINS?

While known facts furnish a basis for understanding the marked similarities that sometimes exist between biovular twins, considerable difficulty is experienced in explaining the differences that occur in twins known, or assumed, to be uniovular. Why are these twins not actually identical? The answer to this query must wait, but there are a few points that may throw some light on the question. In the first place, it is a matter of common observation that the two sides of the same individual are by no means identical. It may be recalled that a few years ago it was a fad with certain newspapers to secure full-face views of prominent people and, dividing them in the median line, reproduce a left side to correspond to the right and a right to correspond to the left. The faked pictures were then printed showing Mr. Blank as he would look (*a*) if the left side of his face were symmetrical with the right and (*b*) if the right side were symmetrical with the left. The hair line, the arch of the eyebrows, the shape of the eyes, the ears, and the mouth, the facial expression, were often very different in (*a*) and (*b*), so much so that in some cases the two pictures would hardly have been supposed to represent uniovular twins. Anatomists are familiar with the rather frequent departures from symmetry in bilateral muscles, nerves and vessels. Occasionally individuals occur with one blue and one brown eye, and indeed it is probable that all symmetrical parts of the body are subject to occasional unilateral variations. The origin of these variations, however, is probably not environmental in the usual sense, since here the environment factor is reduced to its minimum.

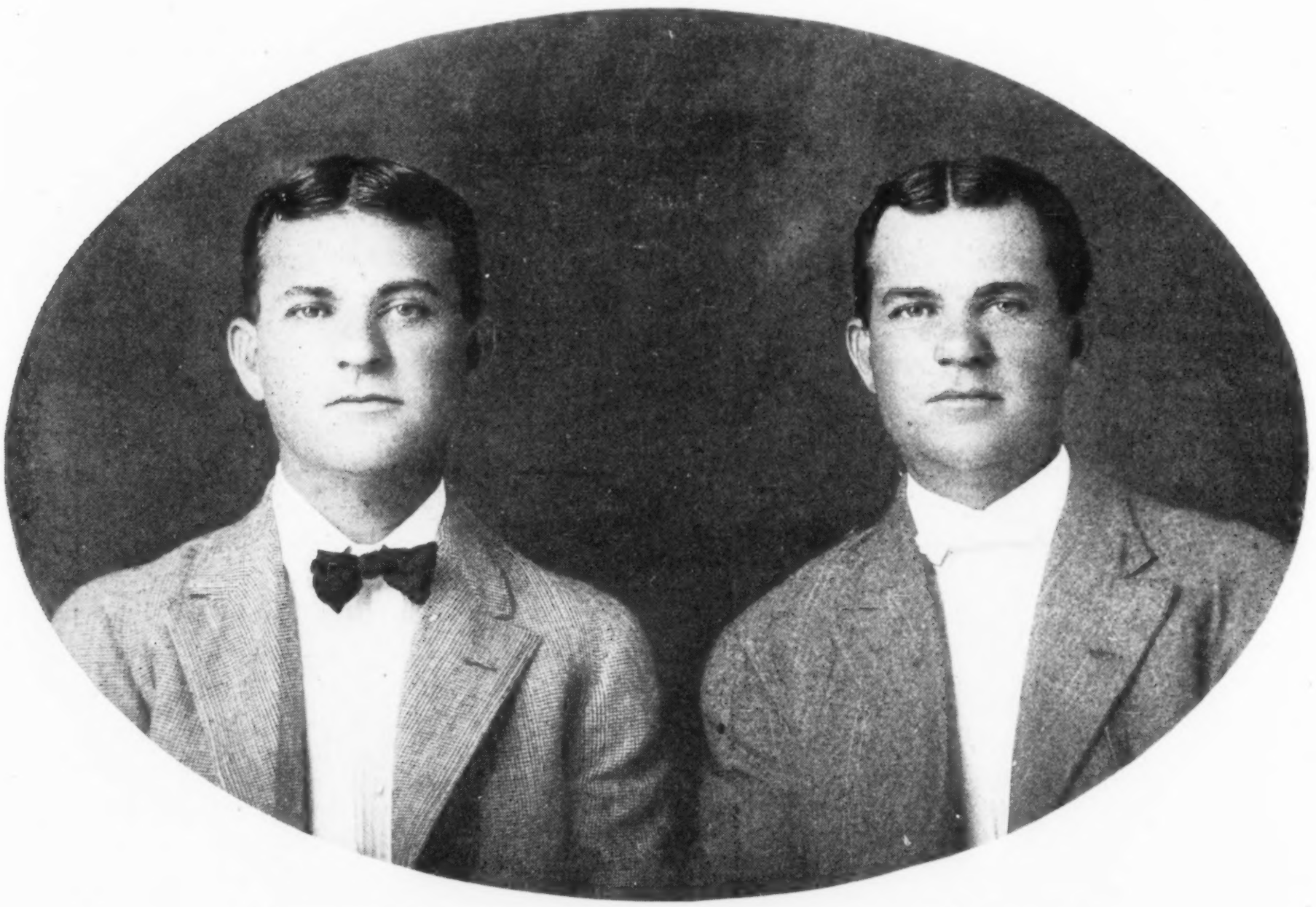
Whatever may be the cause of variation between the two sides of the body when they develop together as a single individual, it is reasonable to expect that they will be equally effective when each half of the blastoderm develops as a separate individual. It might therefore be predicted that uniovular twins would differ from each other in the

[7] See article by Margaret V. Cobb in *Science* N. S., vol. xli, No. 1057, pp. 501-502, April 2, 1915.

same respects and to the same degree as the two sides of the body differ in ordinary individuals.

Whether the fact that a twin is developed from only a part of the ovum while the ordinary individual is developed from all of it makes the two sides of the twin any less variable is not definitely known, but Professor Wilder[8] makes the interesting suggestion that it does and that twins are therefore apt to be more symmetrical than ordinary individuals. Moreover, it is possible, so far as we can see, that occasionally—although rarely, no doubt—they may differ not in one or two particulars but in many, giving uniovular twins which are decidedly different. These facts help us to understand, if not to explain, why uniovular twins are not really identical in the strict sense of the word.

The theoretical considerations briefly set forth in the preceding paragraphs may serve to account for most of the resemblances and differences actually observed among twins. They help us to understand why uniovular twins are not absolutely identical and why biovular twins are often very similar. In the same facts we find an explanation for those intermediate grades of resemblance that often prove so puzzling but which, after all, seem to be due more to the inherent constitution of the germ plasm than to influence of the environment.



TWINS WHO INHERITED NIGHT BLINDNESS

Mr. E. C. McCurdy and Mr. R. G. McCurdy feel very strongly that all identical twins are fonder of each other than ordinary brothers and sisters. The McCurdy twins are also fond of the same things, and they like children and animals, enjoy the same kind of diversions, foods and intellectual interests, and they share an abhorance of bugs, spiders and snakes. They both suffer from night blindness and neither can get about at night, although they both have a good sense of direction. Their handwriting is very different. (Fig. 13.)

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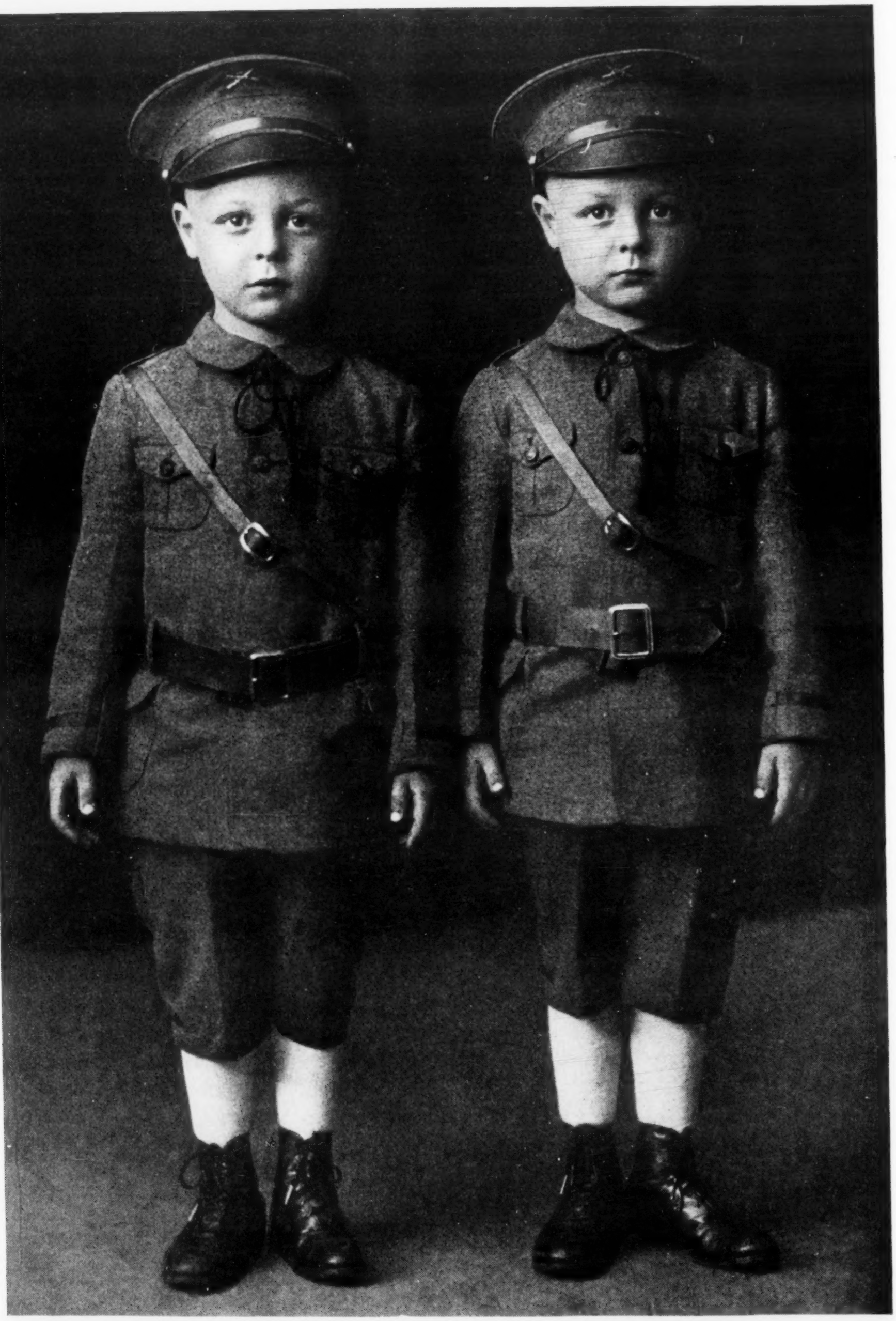
[8] Wilder H. H.: "Palm and Sole Studies." *Biological Bulletin*, vol. xxx, 1916. For a further discussion of symmetry in twins see "The Biology of Twins," by H. H. Newman, University of Chicago Press, 1916.



TYPICAL IDENTICAL TWINS

These sturdy little twins are certainly as much alike as any two peas. It would be interesting to watch them throughout their lives, particularly should they live in different countries, subjected to different climatic conditions. (Fig. 14.)

PHYSICAL CORRESPONDENCES IN TWO SETS OF DUPLICATE TWINS[1]

Striking Degree of Identity Shown in Bodily Measurements and Skin Patterns of Palms and Soles

HARRIS HAWTHORNE WILDER
Professor of Zoology, Smith College

We are now, thanks to the long-continued researches of *Newman and Paterson,* absolutely certain that all the members of a single litter of young armadillos come from what is originally one egg, fertilized by one spermatozoon, and that the striking similarities in certain details of the individual members are due to the fact that all develop equally from the same germ-plasm and thus inherit the same characters.

Human twins of the duplicate type[1] show precisely the same degree of correspondence in similar parts, for the friction-ridges of the palmar and plantar surfaces, made from the fusion of epidermal units (scales?) in rows correspond morphologically very closely to the rows of scales in the armadillo carapace. It may thus be expected *à priori* that the degree of correspondence in the two cases would be about the same, and this, as nearly as can be estimated by the inspection of many cases in each, seems to be the case. Both in normal sets of armadillos, and in man, in the rather frequent cases of true duplicates, we have undoubtedly instances of typical *polyembryony,* with remarkable correspondences in numerous characters, more than is likely to be found in single individuals from separate eggs.

Naturally on the basis of development of twins from either a single egg or from two separate ones, there must be two and two only sharply defined classes, with no possibility of intermediate or transitional forms, and consequently the presence of *doubtful cases,* where, perhaps, neither the facial resemblance nor the palm and sole configuration is absolutely conclusive, threatens the security of the whole theory. It is very encouraging, however, to hear from Newman a plea for the classification of certain doubtful cases formerly published by me as such, under the head of true duplicates, where the departures from identity are only of about the same grade as those occasionally met with among his armadillos, where there is absolutely no doubt that they are from a single egg, and therefore duplicates.

It is also quite possible, on the other hand, that either fraternal twins, or children of different births but with the same parents, may show many similar qualities, since very similar combinations of character may chance to occur. Indeed, with all the possibilities of linkage, and with the consequent tendency to the association of large groups of characters, it would be unlikely that such duplications did not occasionally occur. One such case has come under our direct observation, where there are three sisters in a certain family, two of them fraternal twins, and where the younger single sister so closely resembles one of the twins that she is generally considered by strangers to be herself the other twin, while the latter is of a quite different type, markedly unlike the other two. Here, evidently, is a case of three distinct eggs, two born at the same time, and one at a subsequent birth, but with a similar composition in the germ plasm of this latter and one of the two born simultaneously.

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[1]The term "duplicate," which the author uses throughout this article, has the same meaning as the term "identical" used by the other authors writing in this issue.—EDITOR.

STRIKING SIMILARITY IN PALM AND SOLE PRINTS

In several papers during the past twenty years I have put forth as an exact criterion of the degree of bodily correspondence between twins the use of the friction-skin patterns covering the surfaces of the palms and soles; parts the individual character of which is now well known. Sir Francis Galton and others, notably Féré, have made careful comparisons of the finger-print patterns, with for the most part rather inconclusive results, but in my opinion these areas are too small and the variations too slight to serve well for the purpose. The larger area presented by an entire palm or sole, on the other hand, allows the delineation of a much more extended pattern, or rather a series of patterns, in which the general configuration of the whole surface may show a striking similarity not even noticeable in a single detail of the size and importance of a finger-print only.

The result of the study of some fifty sets of twins in this particular justifies me in making the following claims:

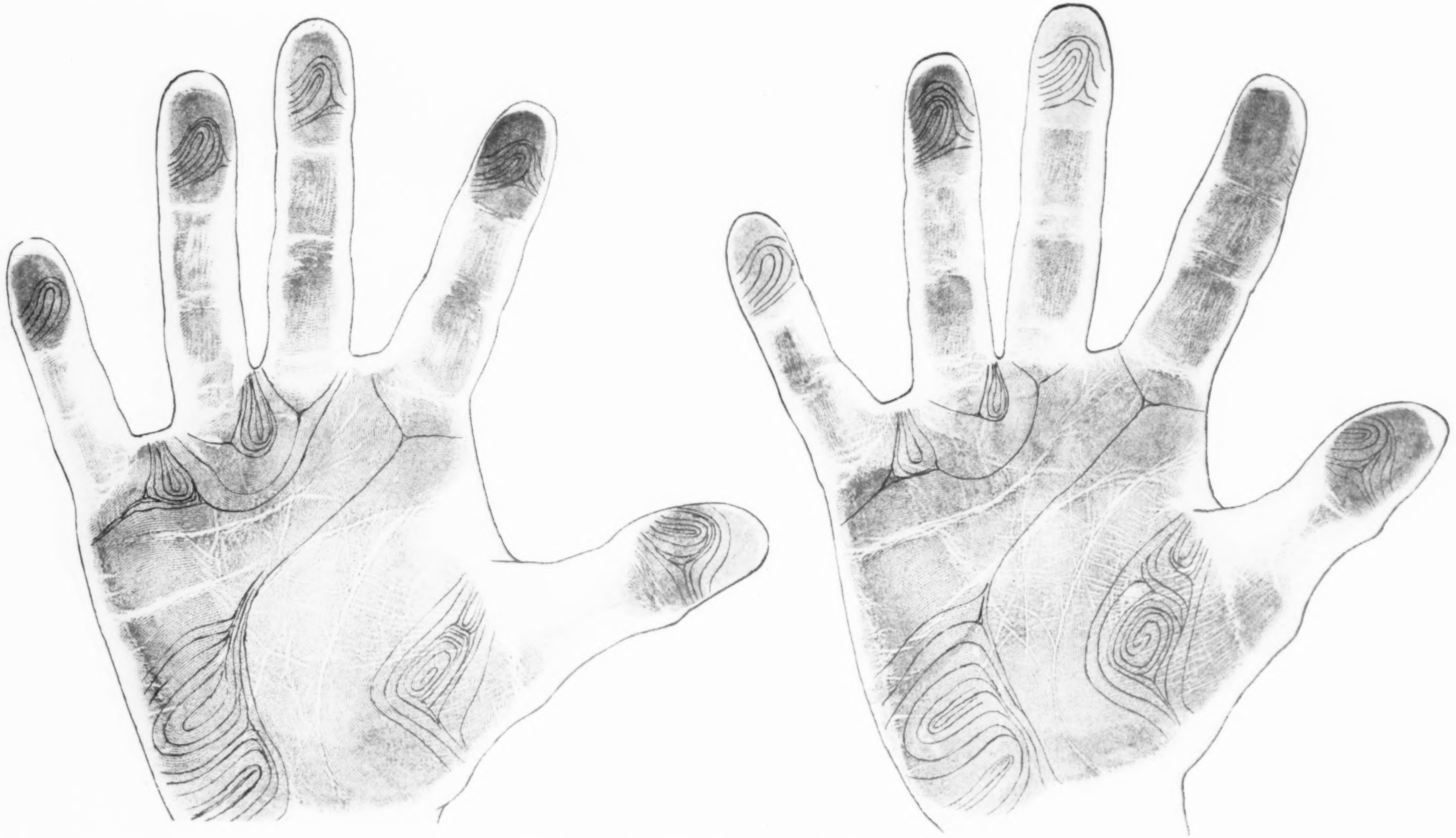
1. The friction-skin configuration of twins corroborates the conclusions based upon the general physical appearance, that there are two distinct types of human twins, *duplicate* (or identical) and *fraternal*. Twins of the first type are monochorial at birth, and represent typical cases of polyembryony, similar to the normal condition in armadillos; those of the second type are dichorial, and represent simply cases of multipary, the normal condition in many small mammals like dogs and rabbits.

2. Twins of the first type show the high degree of facial and bodily resemblance noted throughout this magazine and illustrated through photographs; those of the second type either may or may not look alike, as in the case of any brothers or sisters of distinct birth. Twins of the first type are necessarily of the same sex; those of the second may be either of the same or of opposite sex, as in any two children of one family.

3. The correspondence in the friction-skin configuration is confined to the general plan of the surface as a whole and does not extend in the least to the finer details, the "*minutiae*" of Galton. Thus a loop pattern upon a given area of the right hand of one twin will be found, usually to about the same degree of development, in the corresponding place on the right hand of the other, but there will be no similarity in the number of individual ridges of which the loop is composed in the two cases; technically, the "ridge-count" in the two cases will be different. The two will present the same painting, but with different brush-marks. Heredity determines with considerable precision the occurrence and arrangement of patterns and other larger features, but the execution of them, as drawn by the ridges, is wholly individual, and is *quite beyond the limit of hereditary control*.

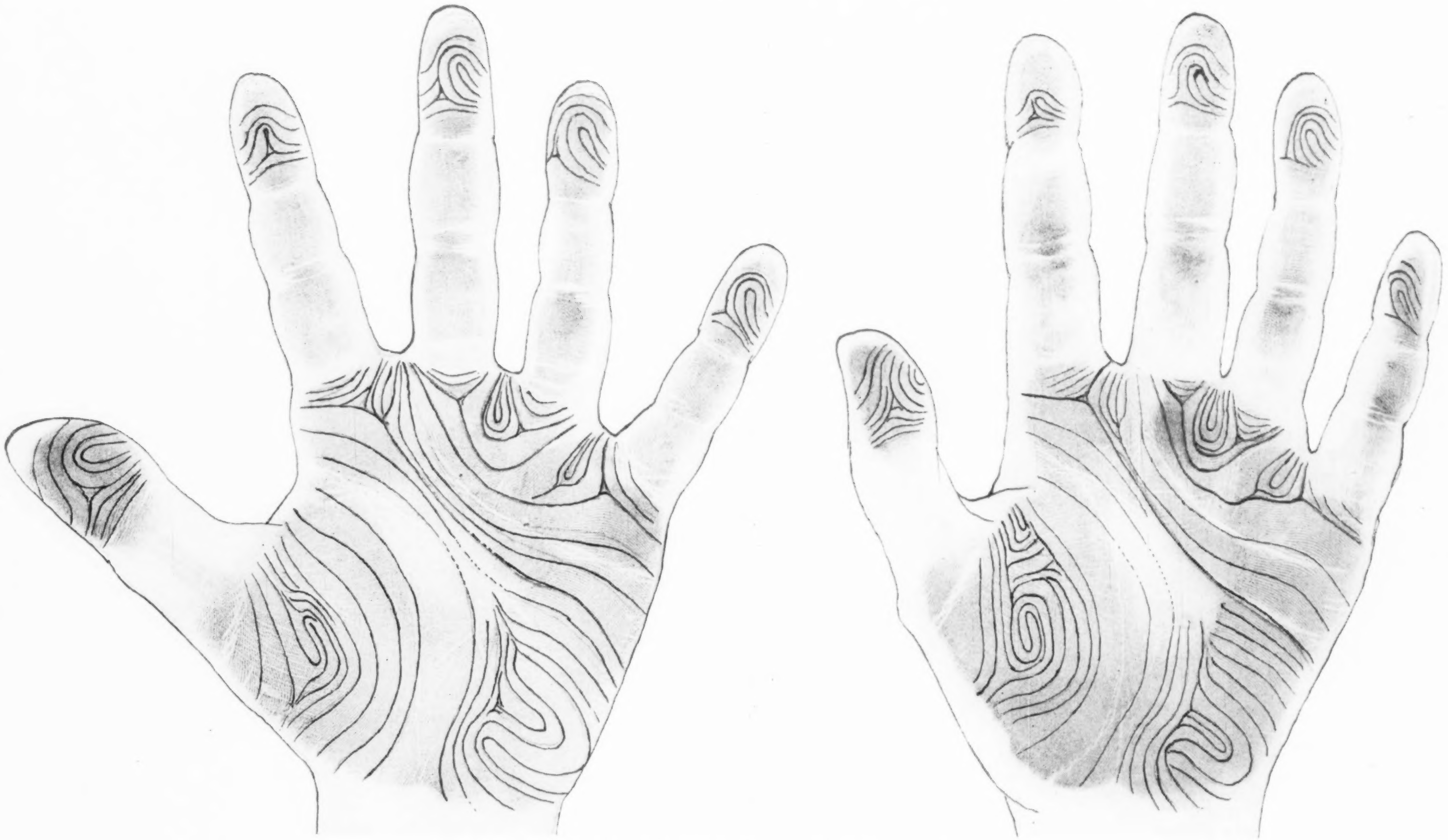
4. Not only does the degree of development of a given pattern in the two twins differ within considerable limits, but it frequently happens that a definite pattern in one twin may be represented in the other by nothing more than a convergence of lines representing the last vestige of the pattern in question. In such cases, however, there is always a well-marked and definite area left for either the pattern or the pattern vestige, thus keeping the general plan of the whole area.

5. In duplicate twins there is, in both hands and feet, a marked correspondence between the two sides, so that the right and left hands of each twin correspond as completely as do the right or the left hands of the two individuals. All four of the hands involved are thus duplicates of virtually the same picture, and the same phenomenon is shown in the four feet. It is true that in normal single individuals some form of bilateral symmetry between the two sides is often found, but this is seldom as complete as in duplicate twins. There are found also all grades of dissimilarity between the two sides, while they are often entirely unlike. Then, too, if



PALM PRINTS OF THE M—— TWINS (male)

Prints of the left hands of Henry (left) and Bernard (right) when these twins were twelve years of age. The lines of interpretation are traced out with India ink upon the actual prints. "The correspondence in the friction-skin configuration is confined to the general plan of the surface as a whole, and does not extend in the least to the finer details." (Fig. 15.)



PALM PRINTS OF THE M—— TWINS (males)

Prints of the right hands of Henry (left) and Bernard (right). "A loop pattern upon a given area of the right hand of one twin will be found, usually to about the same degree of development, in the corresponding place on the right hand of the other, but there will be no similarity in the number of individual ridges of which the loop is composed in the two cases." (Fig. 16.)

the hands are similar the feet are likely to be unlike, and vice versa, so that complete correspondence between the two sides of an individual, and extending to both hands and feet, is extremely rare in single individuals, or may be said never to occur, while in duplicate twins the phenomenon is universal and occurs in both members.

As an excellent illustration of the palm and sole prints of duplicate twins we may first present a complete set from the two M—— boys of Portland, Me., taken about fourteen to fifteen years ago when they were twelve years old. Aside from being perfect duplicates these prints show in the hands the full set of eleven possible patterns to be expected in a palm when in its most complete form, as follows:

5 apical patterns ("finger-prints").
4 interdigital patterns (below the four intervals).
1 thenar (at the base of the thumb).
1 hypothenar (upon the fleshy pad on the side of the palm corresponding to the little finger).

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11

As is universal in man, in cases where these patterns occur at all, the first interval between thumb and index, is found in close association with the true thenar, placed just below it, together making a sort of double pattern at the base of the thumb. As is also usual in such cases the interdigital member of this compound pattern is small or vestigeal and is represented by a simple loop, opening upwards or distally between digits 1 and 2. On the two left hands, as would be expected from the fifth rule above, the record is nearly as complete as to the presence of the eleven patterns, save that in both the second interdigital, between digits 2 and 3, is wanting, although its place is defined clearly by a marked-off area where it would be expected. This pattern is normally of rare occurrence, and even when present is scarcely ever more than a small loop, involving few ridges. A whorl here has not as yet been reported.

The occurrence of all the typical eleven palmar patterns, such as is seen in all four of the hands of this set, is in single individuals one of the rarest phenomena. Among more than 1,200 single individuals my collection shows it but once or twice. The combination of the true thenar with the first interdigital is almost constant when either pattern appears at all, but in the white race this is only in about 4% of all cases, so that in any two individuals taken at random, if one of them has this pattern, the other has just one chance in twenty-five of having it also. One must acknowledge, however, that in children of the same family, where one parent has such a pattern, it is almost certain to appear in all or nearly all. Similarly, the percentage of occurrence of each of the other patterns must be reckoned with by itself, and the total chance of the appearance of each and every one of the typical eleven in any one individual becomes very slight. The chance of this complete occurrence in any two brothers, not twins, is naturally but one in a number represented by the square of this first number, naturally so large a one as to practically preclude its appearance otherwise than as the result of some genetic principle which must be considered as causal.

CORRESPONDENCE IN BODILY MEASUREMENTS

For many years now this case of the two M——s, with its many features that have to be duplicated, has been my best case, because of the many separate features involved, but recently there has appeared a second case, equally complete, where, too, in addition to the palm and sole prints, there has been obtained a full set of bodily measurements. These are the B——s, students of Smith College, and evidently, from the close facial and general physical correspondence, duplicates. From the tracings, which are here presented, instead of the actual prints, the complete representation of all eleven patterns is evidently as good as in the other case.

SOLE PRINTS OF THE M—— TWINS (males)

The prints at the top are those of the right feet of Henry (left) and Bernard (right); those shown at the bottom are of the left feet of Henry (left) and Bernard (right), the lines of interpretation being traced out with India ink upon the actual prints. Although the individual ridges may seem to differ to a large extent, the general pattern of the whole surface shows a striking similarity of outline in cases of identical twins. (Fig. 17.)

The three last interdigital patterns, those of the upper row, are, with the exception of the first one of this row, really the second interdigital, on the left hand of Mabel, large and well-developed, rather better, in fact, than in most cases in the M—— hands. There is again almost a failure of the hypothenar, also in the left hand of Mabel, which shows the other lack. The right thenar of May is also weak, but well indicated. In only one of the four was the little extra loop (= first interdigital) printed, the left of May, but the prints are probably deficient in this region in the others, owing to faulty technique in printing.

The feet of both sets, as in the case of the hands, happen to be decidedly similar to the M——s, and with the same slight discrepancies, occasionally amounting to a lack of harmony in one of the main features, as has been noticed in the hands. For instance, note the third interdigital of the left feet of the two M——s, where the ridges taper to a point, but develop no lower triradius, as in the rights; also the fourth, or last, interdigitals of the two B——s, which show but one real pattern out of the four, the one on the right foot of May.

RESEMBLANCES CONTROLLED BY GERM-PLASM

Recapitulating, the general similarities, with various minor departures therefrom, appear in these two cases about as in other typical cases of twins that closely resemble each other, and which, for these and other reasons, may be considered *duplicates*. The resemblance is close, but not exact, and never extends to the ridge details, the minutiae of Galton. The conclusion is hard to avoid, that, as has been done by Newman and Patterson in the similar correspondence of the ridges of the carapace of armadillos, the correspondences are of those parts that are under the control of the germ-plasm, and that where there is no definite correspondence the development is left to other forces, whatever they may be.

The bodily measurements of the B—— twins were taken in the nude by a graduate student, Miss Margaret Washington, and constituted a part of the similar careful measurements of 100 students used in the preparation of a thesis. These twins were taken towards the end of the series, after the measurer had had the greater part of her practice, and the results may be relied upon as accurate. The measurements were taken in millimeters by the anthropometer of Martin, made by R. Hermann, of Zürich, with the occasional use of other instruments from the same source. Miss Washington followed, both in the selection of the measures to be used and the technique by which the measures were taken, the International Prescription of the Congress of Geneva, in 1912.

The measurements of the two are as follows:

	May	*Mabel*
Total stature	1668	1669
Arm stretch	1631	1621
Height; tragus	1522	1521
Height; vertebra prom.	1431	1431
Height; incisura sterni	1361	1360
Height; acromion	1349	1361
Height; nipple	1248	1233
Height; umbilicus	1030	1020
Height; ant. spine il.	966	964
Height; trochanter	911	891
Height; symphysis	879	885
Height; olecranon	1055	1080
Height; styloid radius	822	838
Height; end middle finger	621	639
Breadth; biacromial	340	337
Breadth; cristal, il.	255	254
Breadth; spinal, il.	250	256
Breadth; trochanteric	205	205
Breadth; nipples	190	195
Breadth; thorax	232	236
Depth; thorax	175	175
Length; foot	254	251
Stature; sitting	848	840
Vert. prom; sitting	620	613
Incisura sterni; sitting	551	530
Acromion; sitting	539	530
Head length	185	185
Head breadth	142	142
Frontal breadth	97	96
Breadth between eyes	28	27
Zygomatic breadth	116	116
Breadth of jaw, angle	96	95
Chin-hair length	185	188
Chin-nasion length	122	122
Nasion-prosthion	76	76

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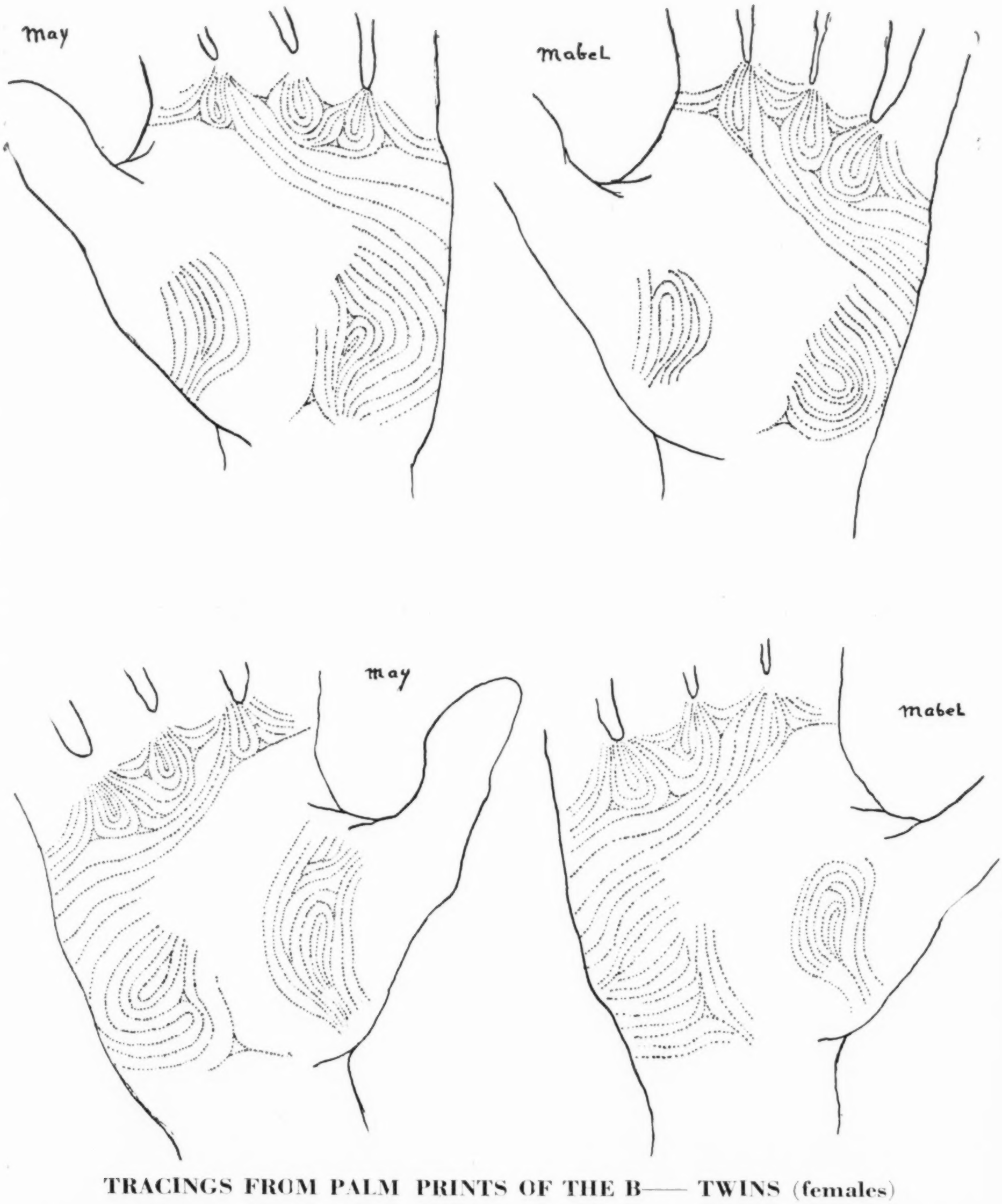
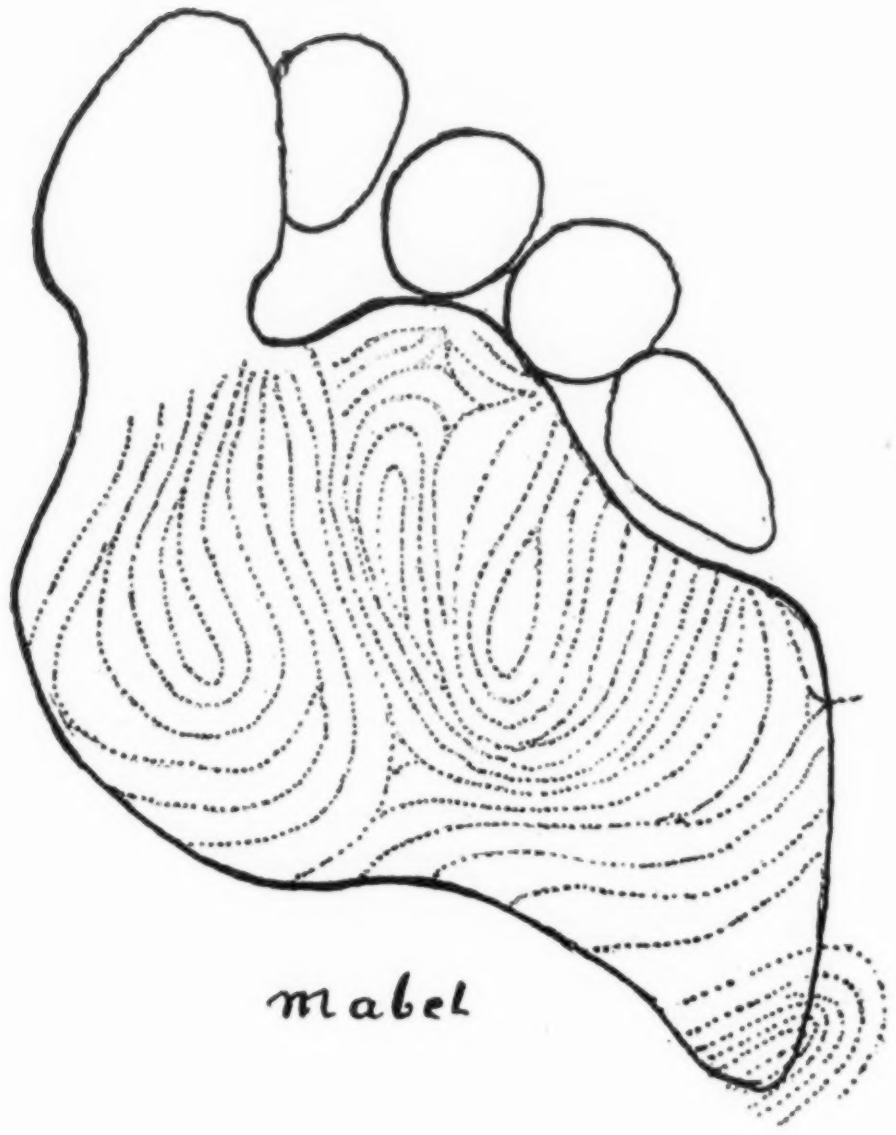


TRACINGS FROM PALM PRINTS OF THE B—— TWINS (females)

The two at the top are of the right hands of May and Mabel at eighteen years of age Those at the bottom are of the left hands of the same twins. These illustrations were made by tracing the essential lines through the actual prints by means of carbon paper, and thus transferring them to blank white paper. They thus correspond to the inked lines seen on the prints in Figures 15 and 16. (Fig. 18.)



TRACINGS FROM SOLE PRINTS OF THE B—— TWINS

Made in the same manner as those shown in Fig. 18. Those at the top are of the right feet, and those at the bottom, the left feet of May and Mabel. "Heredity determines with considerable precision the occurrence and arrangement of patterns, and other larger features but the execution of them, as drawn by the ridges, is wholly individual, and is quite beyond the limit of hereditary control." (Fig. 19.)

	May	*Mabel*
Length of nose.....	60	60
Breadth of nose	29	28
Length of ear	58	58
Breadth of ear	31	29

Color of eyes, hair, and skin, obtained by comparison with the standard numbers of the tables prepared by P. Hermann, namely, the eye color table of Martin; the hair color table of E. Fischer, and the skin color table of Luschan. The numbers are as follows:

Color of eyes	No. 15	15
Color of hair	No. 8	8
Color of skin	No. 3	3

At the time of the measurements the twins were eighteen years old.

From these tables, which give the actual height from the floor of numerous points upon the trunk and limbs, many other measurements may be obtained through subtractions. Thus the total length of the arm is obtained by subtracting the height of the extended middle finger from that of the acromion; that of the arm alone by subtracting the height of the styloid process of the radius from the same height, that of the acromion. Similarly the olecranal height, which is that of the head of the radius, with the styloid height taken from it, is exactly the length of that bone and may be considered as that of the forearm.

To apply this, the total arm-length of May is 1,349 — 621, or 728 mm.; while that of Mabel is 1,361 — 639, or 722, showing an insignificant difference of 6 mm. For the arm alone, without the hand the figures are respectively 527 and 523. It will be noticed that the height of the acromion differs almost more than any other height, which is due to the impossibility of always holding the shoulder skeleton, with its mass of muscles, at just the same level.

For this cause there is always fully as much variation in the measurement of the acromial height of the same individual taken at different times; and as the total arm lengths are so nearly alike in the two twins, it is fair to consider the normal, or average, acromion height as practically the same in both.

The leg height, or that from the head of the femur to the ground, is quite impossible to get directly, owing to the depth to which this part of the femur is imbedded in the soft parts. Many workers take as a good substitute the height of the iliac spine, and from this subtract 40 mm.; others subtract the total sitting height from the total standing height. By the first method the two twins, in the order used here, have as leg lengths, respectively, 926 and 924 mm.; by the second the leg lengths are 820 and 829. These last are not really leg lengths at all, but represent merely that portion of the total stature remaining after the subtraction of head and trunk, and hence are much less than the true leg length, or that of the femur and tibia together with that portion of the foot used in standing.

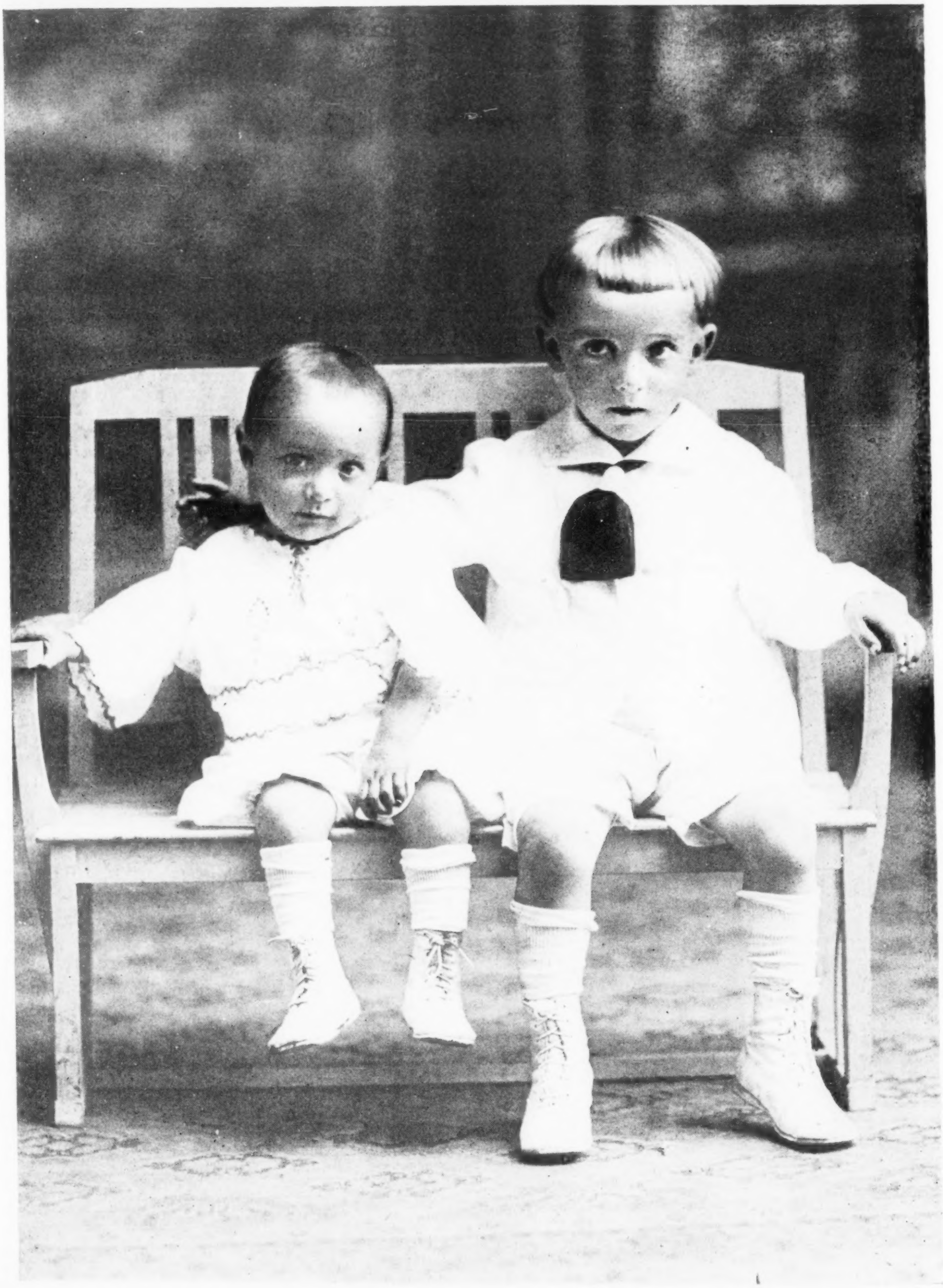
The trunk length, measured to the plane of the ischia in the sitting figure, may either include the neck vertebrae and be measured from the upper plane of the atlas, or may be that of the trunk alone, beginning with the thorax. In the first case one may also use the tragus height or that of the subnasale, both of which fall at about the plane sought when the head is placed in the usual position, with the eyes looking straight forward; in the second, one has the choice of either the suprasternal notch or the vertebra prominens. These heights are in all cases measured down to the plane of the table upon which the subject is sitting and give the various trunk heights, with or without the neck. With the inclusion of the neck, using the vertebra prominens for the upper limit, the trunk lengths of the two girls are, respectively, 620 and 613, the slight difference being easily accounted for by a slightly different degree of relaxation in the two spinal columns, causing a similar difference in the shape of the lumbar curve. Using the incisura sterni, however, and thus excluding the neck, the figures given are 551 and 530. These are considerable, rather more than in other cases, and although they are possible, it is quite likely that we have here a clerical error, made during the measurement or the later copying, as the fig-

ures used here were twice copied. The fact that in the second twin the same number, 530, is also given as the acromial height, and occurs on the list immediately beneath it, suggests such an error as an easily explained possibility.

CLOSE IDENTITY IN PHYSICAL STRUCTURE

Taking, now, the figures directly from the tables, there are some very striking similarities, amounting in a few cases to complete or practical identity. Thus, starting with a total stature of 1,668 and 1,669, we find the height of the vertebra prominens and that of the incisura sterni the same exactly, while the height of the tragus has but a single millimeter of difference. The heights of the very mobile shoulder girdle and of the parts of the arm depending from them, as already explained, cannot be expected to be constant, but the length of the arm and its parts in the two, as obtained by subtraction of heights from one another, is very close. As for breadths, the biacromial differs by but 3 mm., the cristal, across the hips, by 1, and the trochanteric not at all. In thoracic measures we have 232 x 175 and 236 x 175, where the 4 mm. difference in one dimension alone is negligible. The length and breadth of the two heads is identical in both twins, 185 x 142, and it is also significant that the facial measurements show so close a similarity. The few measurements of the soft parts, the nipples and the umbilicus, are of minor importance, as they do not depend upon a bony support and are easily changeable. Taken in general, there is a surprising degree of identity in the bodies of these twins.

This test of bodily measurements offers an important field in the investigation of twins. They should be measured while young, before the varied experiences of after life have effected much modification, but after maturity is reached. It would be also of interest to get several series of such measurements of the same sets of twins during growth, from infancy to maturity. From such studies could be learned, for instance, the effect of various illnesses undergone by one twin and not the other, and in such things could be found explanations for many of the slight lacks of complete correspondence which are out of harmony with what would be expected in genuine duplicate twins.



A MARKED DIFFERENCE IN GROWTH

These little twins have both had four years in which to grow. Just what were the forces that checked the development of the smaller boy, could not be ascertained. Very likely it was an early illness. The mother, Mrs. S. Cooper of Newark, N. J., states that the "smallest boy is doing fine now and is very bright and lively." We have no evidence that these are identical twins. (Fig. 20.)

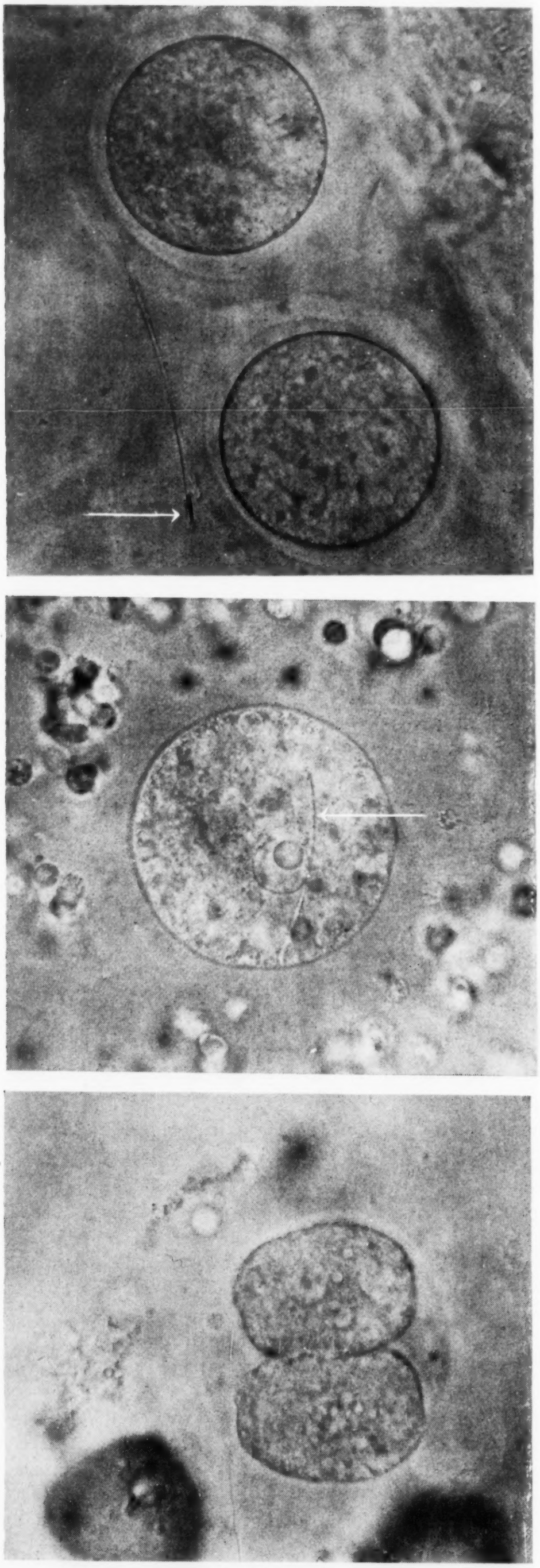


FIG. 21

Carriers of the Germ Plasm

The two large spheres in the top picture are egg cells, alive in Ringer's solution when photographed. A single whip-like spermatozoon may be seen at the point of the arrow. The penetration of an egg cell by a single spermatozoon results in a cell, the fertilized egg, which has within itself the power of developing into a new individual when properly nourished.

The middle picture shows an egg cell which has been penetrated by a spermatozoon. The unabsorbed tail of the latter can be seen next to the single nucleus produced by the fusion of the egg and sperm nuclei.

A living egg in the two-cell stage appears in the illustration at the bottom. Under normal conditions the two cells into which the egg cell divides after fertilization remain together and become the millions of cells which form a single individual. After the early cell divisions, however, each of the cells still possesses the potentiality for development into a perfect individual, and may do so if separated. Human identical twins are produced by the breaking apart of a single egg in the two-cell stage, or very soon after, and resemble each other closely because of their identical heredity. Ordinary twins develop from two wholly independent egg cells which merely happen to be fertilized at about the same time. Such twins resemble each other no more than ordinary brothers and sisters. These photomicrographs, of white rat eggs cells magnified 500 diameters, are by Dr. Joseph Long, of the University of California.

TWINS PROVE THE IMPORTANCE OF CHROMOSOMES

The Most Powerful of All Forces Operating to Control Human Destiny—"The Most Important Things in the Whole Known World"—Are So Small That a Microscope Is Required to See Them

FREDERICK ADAMS WOODS

Lecturer on Biology, Massachusetts Institute of Technology

WE KNOW at present that the chief, though probably not the sole, determiners of differences among higher animals lie in those infinitely important and complex microscopic granules known as chromosomes. The material out of which they are formed remains constant in every living cell, and they are visible and subject to numerical counting, at times of cell division. Most people have never heard of chromosomes. But they will if they live long enough; unless, perchance, some other word is introduced to take its place, for chromosomes are among the most important things, and, considering their size, they *are* the most important things in the whole known world. A generation from now the public will have heard of chromosomes just as today the public has heard of evolution and of bacteria. Chromosomes and heredity are in a way synonymous, but heredity is used in various senses by different people. When we say chromosomes, we speak of things tangible, or at least, if we cannot actually touch them, they are objects that can be seen and measured and counted.

Identical twins are among the most interesting of beings, because they alone have the same kind of chromosomes. This is due to the fact that very early in embryonic life there occurs an almost absolutely precise division of the chromosomes, so that two individuals are developed side by side, each controlled by similar determiners. The extreme resemblance of identical twins is itself a proof of the importance of these determiners (chromosomes), for otherwise we cannot explain all the phenomena.

It is known as a result of a great number of observations that children on the average resemble their fathers, and their father's family, quite as much as their mother's and their mother's family. The far-reaching significance of this every-day fact, like most wonders that are ever before our eyes, is apt to be overlooked. Even this fact alone is a proof of the extreme importance of chromosomes, since the egg is many hundred times as large as the sperm, but the chromosomes of the egg are no larger than those of the sperm. They are practically the same size, and presumably of corresponding chemical structure and importance.

Twins, then, are not needed to prove the extreme importance of chromosomes. What twins prove is this: They prove the lack of importance of environment, but only in one aspect and in one restricted meaning.

There is a great deal of loose talk about environment, all of which means nothing and gets nowhere. The only discussions that are today worth considering are those which are based upon quantitative measurements.

In a sense, environment is all-important, for without nourishment, oxygen, and warmth, growth is impossible; and without training, education, and social control, the development of the higher traits would not take place. But this environment is customary and expected. The question of practical interest is: How far do *changes* in the

NOT IDENTICAL TWINS MAY DIFFER IN RATE OF GROWTH AS WELL AS IN LOOKS

While it would be a mistake to overlook the influence of proper food upon the development of a child, it is just as great an error not to realize that children inherit different reactions with regard to the same foods. If one child develops more slowly than another, it may be because of its heredity and not because of any environmental influence. (Fig. 22.)

customary environment produce measureable modifications? In order to prove that a modification is due to an environmental change it is essential that the heredity (or chromosome) factor should be a constant. This requirement may be sometimes attained by using a large number of individuals whose average heredity may be reasonably supposed to be the same. For example, there cannot be any doubt but that the striking differences in the growth of dogs, sheep, and other animals, when given greater and smaller amounts of glandular extracts—thyroid, etc.—are really caused by these environmental forces; *i. e.*, a difference not caused by chromosome differences.

STRIKINGLY ALIKE IN OLD AGE

When these pictures were taken in 1915 these twins were about eighty years old. They had never been more than 10 months away from the village of Bethal, Maine, in all their lives. They invariably went for a walk every afternoon at about 4 o'clock, *always* accompanied by the two white cats. (Fig. 23.)

The great lesson derived from the records of identical twins is that the ordinary differences within the uterus of the mother and the ordinary differences within the home life and school life and even adult life are not of sufficient force to modify greatly the control of the chromosomes.

The non-identical or "fraternal" twins have the same chance to become similar through environmental action as the "identical," yet they are not so moulded. Photographs show this in the most obvious manner, and, if as appears from the records of the questionnaires, the resemblances are no greater in physical than in mental aspects, then the far-reaching inference is forced upon us that even mental and moral differences are controlled by forces lying in the primary chromosomes.

This does not mean that *great* changes in the environment may not cause considerable modification in the individual; but the point is that *great* changes are not usual. The very fact that they are great is associated with their scarcity, and under usual conditions of life the physical and mental differences that we commonly observe among our fellow-beings are really due to differences traceable in the chromosomes themselves.

A DEFINITION OF HEREDITY— "NATURE VS. NURTURE" NOT A GOOD EXPRESSION

FREDERICK ADAMS WOODS

THE expression "Nature versus Nurture," introduced originally by Galton, has been very widely adopted, but this prettily balanced phrase is not altogether satisfactory from the standpoint of scientific definiteness. From the artistic point of view we cannot but admire a dainty little bit of word carpentry. We have the two N's furnishing alliteration, and the words nearly balance in weight. The last four letters are identical, and in addition to this the words seem to express well, the same idea as heredity vs. environment for the antithetical forces of nature. But here is already the first objection. The word nature can never be made to mean anything less than all the forces of the cosmos. Surely everything is nature.

Sometimes, again, the word nature is employed in another limited, yet entirely different sense, as meaning the wild-woods, the fields, the clouds, and the birds. The zealot advocates a "back to nature" movement, as though human nature were not a part of nature. In the same way our forefathers invented for us the phrase "natural history," thus suggesting that human history was unnatural or at least non-natural, and that man was apart from the world of organic life.

Of course this sort of criticism is almost inevitable, if we start to dissect the English language. The same objections can be raised against the words heredity and inheritance. We all use these words in different senses with different associative ideas, according to our age, habits of thought, and professional training, even if we are trying to use them in a narrowly defined and technical sense. The word heredity to a biologist, trained in microscopical anatomy and embryology, suggests a single cell—a germ-cell immediately after fertilization. Is it likely that this word suggests the same picture to a man trained in theology or law?

But we shall all have to see the same picture some time—that is, if we are to make the science of heredity part of the curriculum of education, and the best definition of heredity will have to be closely associated with the mechanism of chromosomes and germ-cells, and the clearest pictures will be mentally held only by those who have some ideas of the structures and functionings of these primordial elements.

The use of the word "nature" as synonymous with heredity is associated with an objection beyond the academic one that everything is nature anyway; and that is, because we have the common phrase "human nature," so that when we say the *nature* of that man is bad, we do not know whether we mean to suggest that his bad nature is inherent or the result of bad associates.

Again, we have the familiar phrase applied to kindly souls that he or she has a "good nature." This last idea can only be conveyed if the words are spoken (or read as spoken) quickly. How different is the picture portrayed of one who has a good nature (spoken

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NOTE: In connection with this discussion it may interest some readers to refer to a former article in the JOURNAL OF HEREDITY for February, 1918 (vol. ix, No. 2) on the "Meanings of Genetic Terms." About sixty of the terms commonly used in the subject of genetics are there discussed.—Ed.

quickly) from one who has (accent on the good) a *good* nature. So we may have good-natured people who may be lazy, dirty, and incompetent. It is only by stressing the last word that we can convey in good *nature* anything of the Galtonian usage of the word.

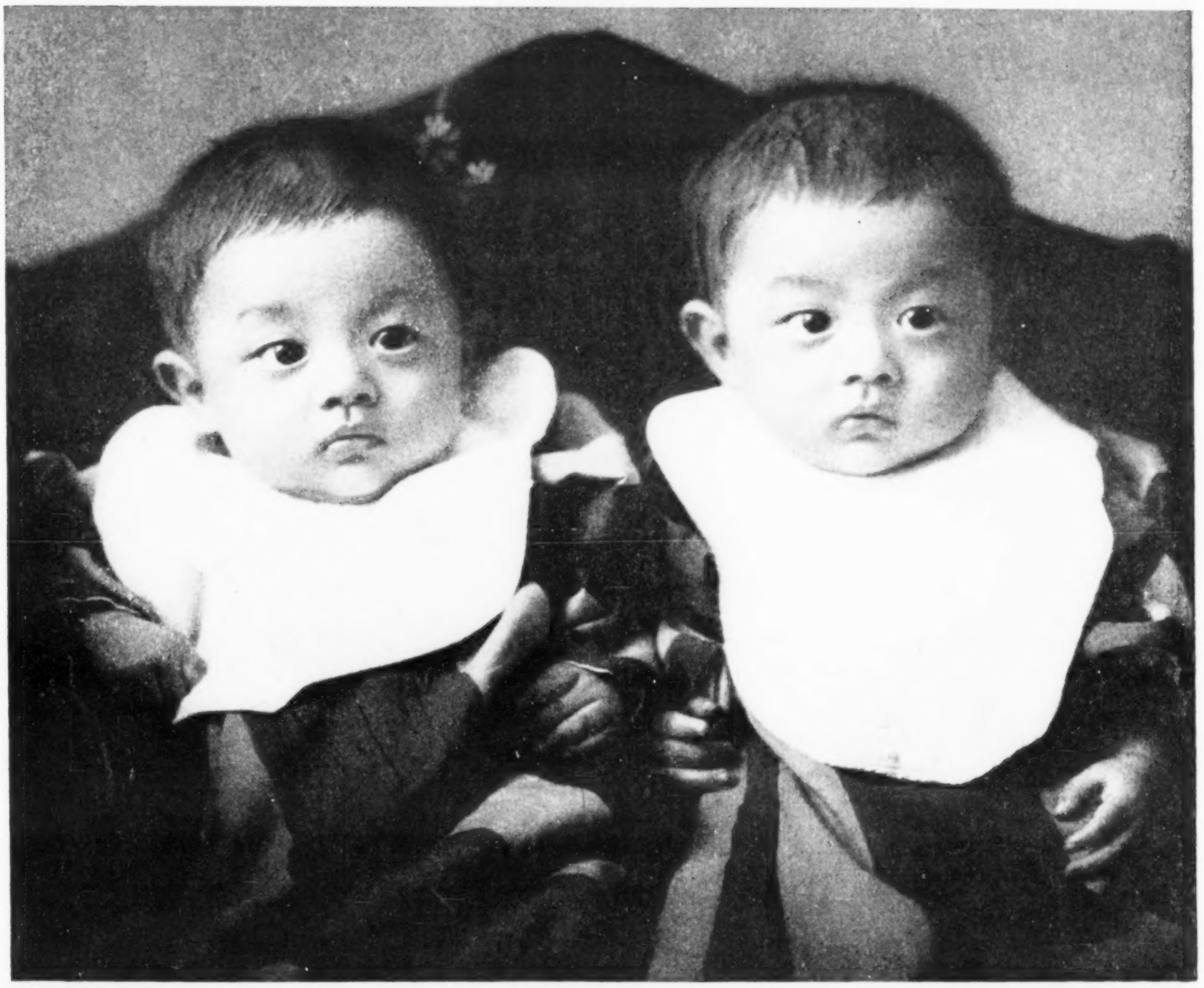
The word heredity is also far from ideal as an expression of scientific exactitude. In the first place, we have our "social heredity" or even our "heredity from God," though these usages are usually pretty clearly differentiated, and it is evident from the text that we are talking about something other than the functioning of reproductive germ-cells. The chief difficulty in using the word heredity is that to many people heredity either means all that one is at birth, or means all that one has for an ancestry. Neither of these conceptions is in accordance with modern views on the method of reproductive generation and therefore it is undesirable to use the word heredity in either of these senses.

All that one is at birth is already a compound resultant of germ-plasm and environment. All that one has for an ancestry may amount to little. It is solely a question of how the ancestral germ-plasms are sorted and arranged in any particular case.

The word "heredity" should be understood to signify all that is contained in the original fertilized cell (zygote) from which all the subsequent cells are, by cell-division, produced. If the chromosomes are found to be the sole intracellular agencies controlling the normal development of the body, then the word "heredity" may be considered as synonymous with chromosomes, and to say a man has a good heredity is to say he has good chromosomes. If, as is more probable, other portions of the cell enter somewhat into the matter, though to a limited extent, then the word "heredity" is almost, though not quite, an equivalent of the word chromosomes.

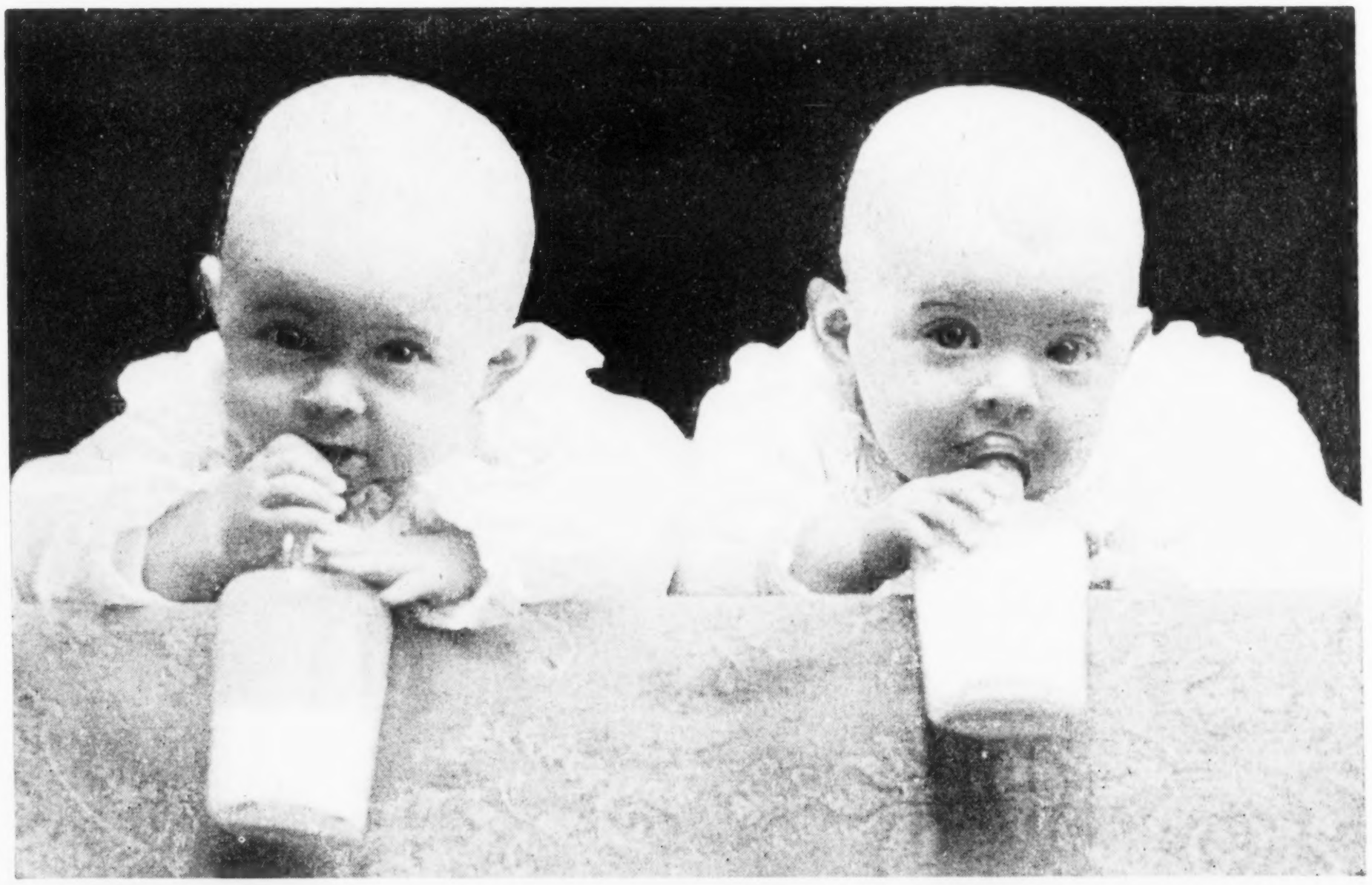
OF THE SAME HEREDITY

George and John Seiffert, of York, Pa., eighteen years old. (Fig. 24.)



IDENTICAL TWINS FROM JAPAN, YEHCHI AND YUJI OGATA, OF TOKIO

(Fig. 25)

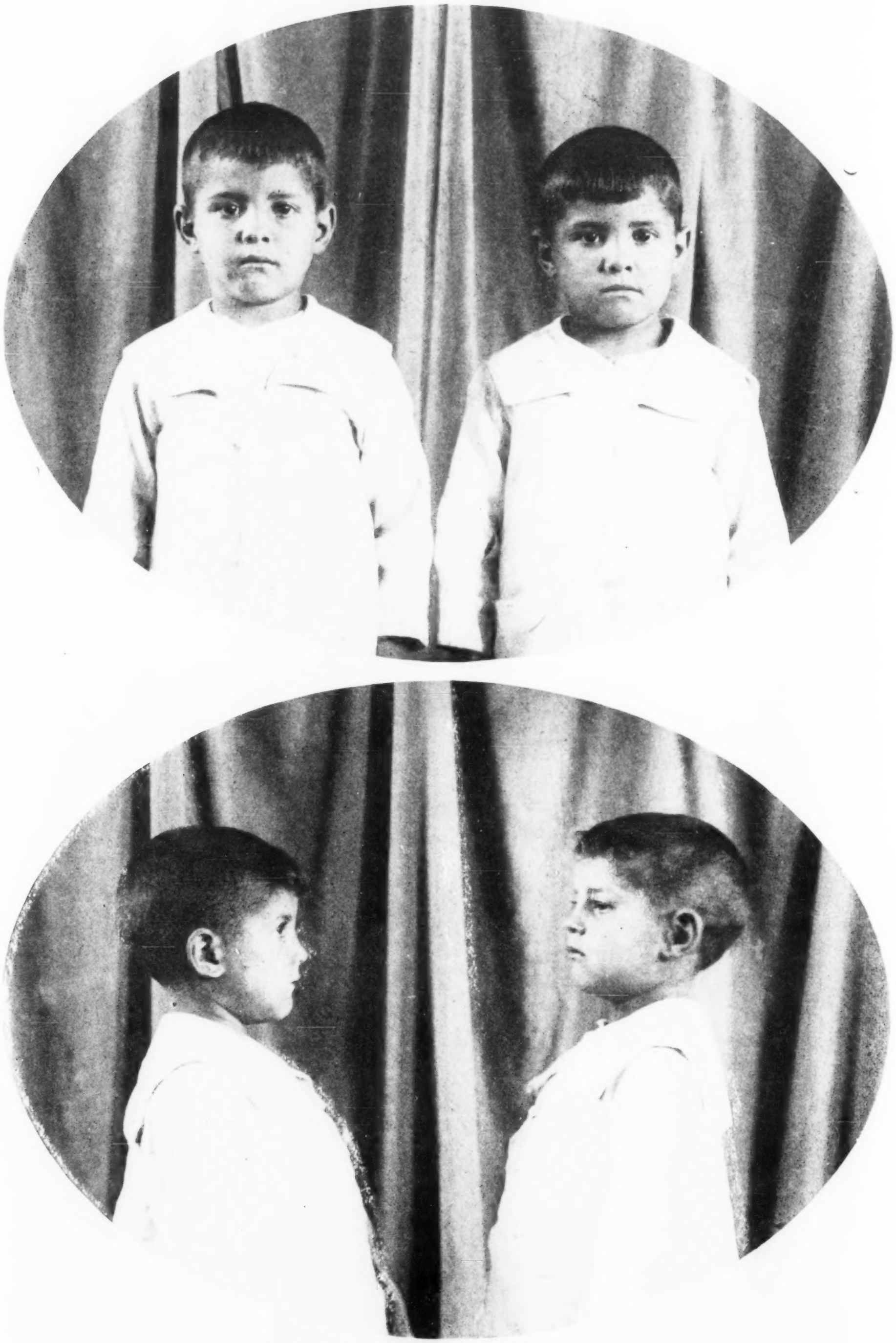


THEY LOOK THE SAME, THOUGH ONE DRINKS FASTER THAN THE OTHER

(Fig. 26.)

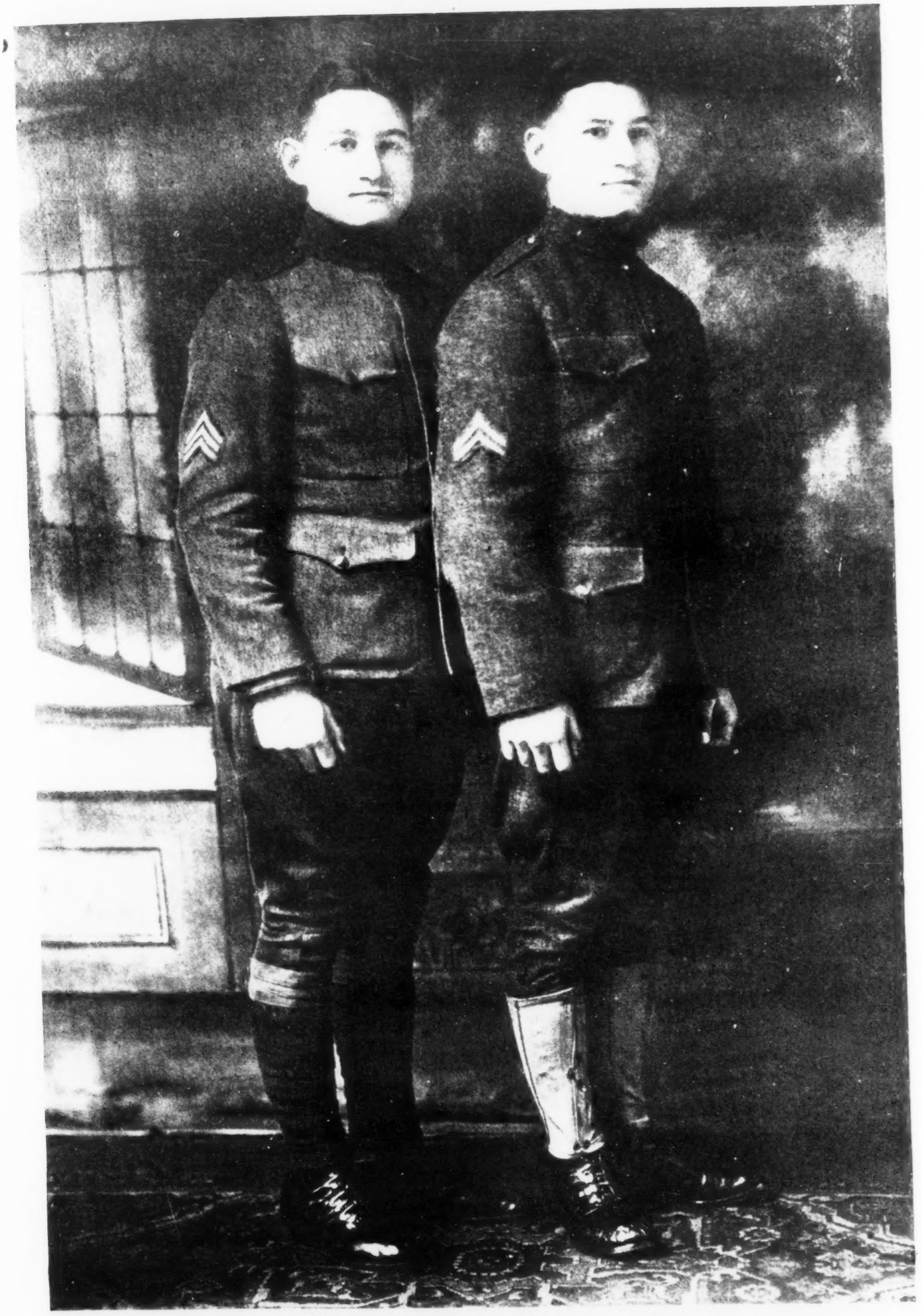
ARE THESE BOYS IDENTICAL?

Appearing at slightly different angles, it is hard to tell if these boys are identical twins and the Association has no data about them at present. They are sons of B. E. Burdick, of Racine, Wis. (Fig. 27.)



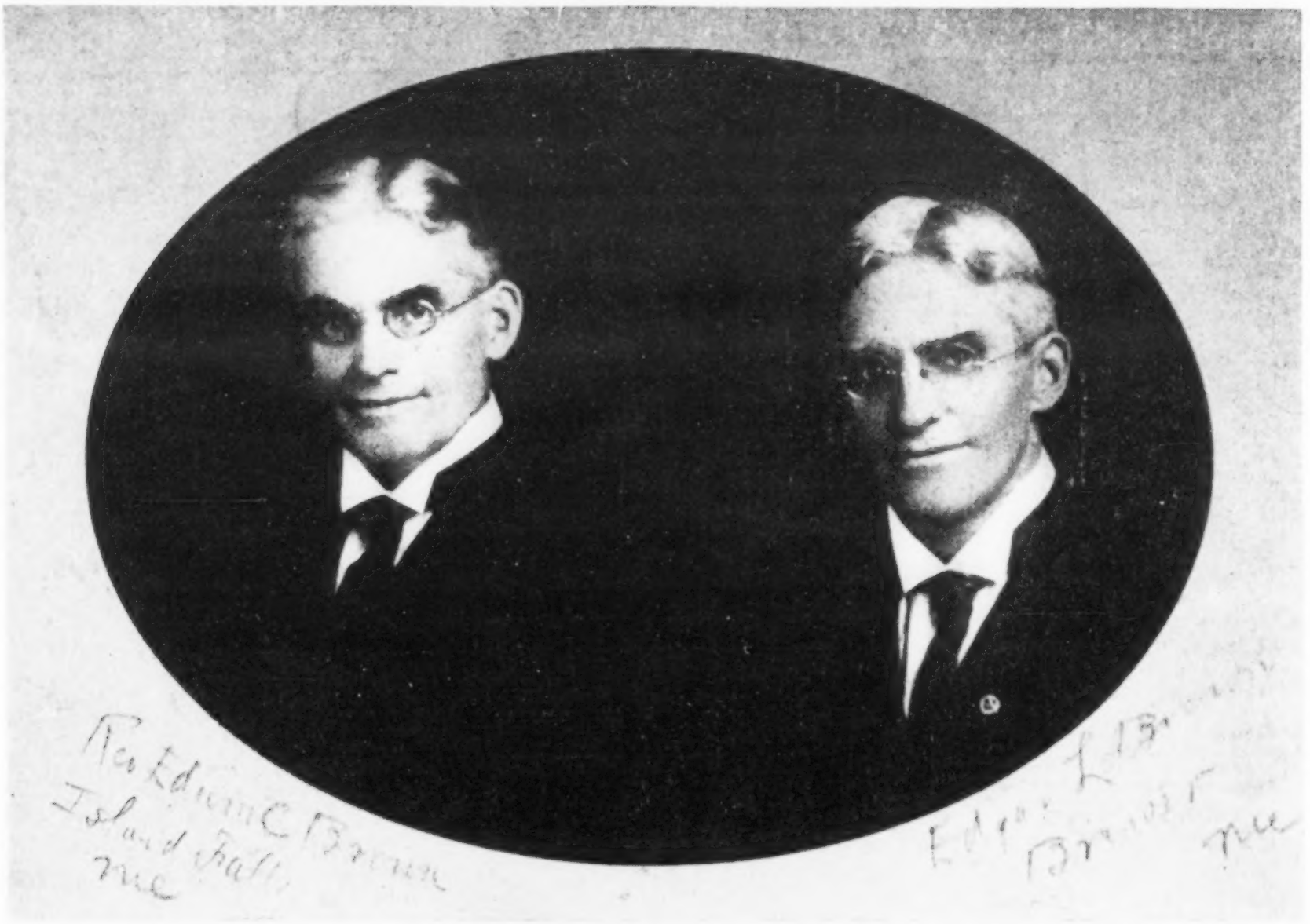
TWO SPANISH BOYS FROM CUBA

From Cuba have come the pictures of Enrique and Armando Brana. These twins were born in June, 1912. (Fig. 28.)



STRIKINGLY SIMILAR IN CHARACTER

The Zermansky twins have a similar love of poetry and music, enjoy the same sports, but differ in their taste for mathematics. Philip dislikes all mathematics except trigonometry, while Mark has been good in all mathematics. They both have slight eye trouble, and their gait is different. Mark was left-handed as a child but was taught to use his right hand. Their writing is strikingly alike; both have a "double-jointed" thumb on the left hand. Mark works hard at anything and does well on examinations, while Philip is inclined to work only at what interests him, and he does not do his best on examinations as he is apt to be nervous. (Fig. 29.)



Rev Edwin C Brown
Island Falls
Me

Edgar L Brown
Brewer
Me

THE BROWN TWINS AT FIFTY-NINE YEARS AND THE HARLOW TWINS AT TEN MONTHS

For fifty-nine years the brothers (top), whose hair is now snow white, have been taken for one another. Edwin is a Congregational minister and has lived in various places, and Edgar a bookkeeper who has stayed in Maine. Both were born with defective eyesight, one in the right, and the other in the left eye. Both are right-handed; for years with similar gait, with tastes remarkably similar, with similar bodily weaknesses, one requiring surgical aid, both with idiosyncrasy against strawberries and acid foods, both with a good sense of locality and direction, and both peculiarly congenial towards each other. Their handwriting is not strikingly similar. Edgar L., 3 Holyoke St., Brewer, Me. (right); Edwin C., Island Falls, Me. (left).

The chances are very great that, like the Brown twins, the Harlows (bottom picture) will remain alike through life. (Fig. 30.)

GENETICS AND EUGENICS

"Genetics is the science which seeks to account for the resemblances and the differences which are exhibited among organisms related by descent."

Eugenics is the study of agencies under social control that may improve or impair the social qualities of future generations, either physically or mentally."

"An exact determination of the laws of heredity will probably work more change in man's outlook on the world, and in his power over nature, than any other advance in natural knowledge that can be clearly foreseen.

"To gain this knowledge is the object of the science of genetics. which proceeds in practice, largely by means of plant breeding and animal breeding for the reason that heredity is less complicated in these organisms than in man, and its operation can be more easily made out. The knowledge so gained finds its application in methods for the improvement of cultivated plants and domesticated animals and, most important of all, in the improvement of the human race, through the science of eugenics."

GENETICS LITERATURE

The annual reports of the American Breeders' Association, published in seven volumes, form one of the most valuable collections of material for students of genetics which has been published in the United States. Volumes I to V are no longer available, but the Association still has on hand a few copies of Vol. VI for sale at $1.00 and Vol. VII-VIII at $1.50.

The Association desires to purchase copies of Volumes I to V of the Proceedings A. B. A., and will be glad to hear from anyone having copies for sale.

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